MEASUREMENT AND ESTIMATION OF EVAPORATION AND EVAPOTRANSPIRATION

A Thesis Submitted
in partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
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to the

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INDIAN INSTITUTE OF TECHNOLOGY KANPUR

OCTOBER, 1975

TO

MY AMMA

CERTIFICATE

This is to certify that the thesis entitled "Measurement and Estimation of Evaporation and Evapotranspiration" has been carried out under my supervision and the results embodied in this thesis have not been submitted to any other Institute or University for award of degree.

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LIST OF NOTATIONS

E_T	Potential evapotranspiration in mm H_2O/day (Penman method)
H	Daily heat budget at surface in mm H_2O/day
R_A	Mean monthly extra terrestrial radiation in mm H_2O/day (Penman method)
r	Reflection coefficient of surface
n	Actual duration of bright sunshine
N	Maximum possible duration of sunshine
σ	Boltzmann constant
T_a	Absolute temperature
e_d	Saturation vapor pressure at mean dew point mm Hg
E_a	Evaporation in mm H_2O/day (Penman method)
e_a	Saturation vapor pressure at mean air temperature in mm Hg
u_2	Mean windspeed at 2 meters above the ground in miles/day
u_1	Measured windspeed in miles/day at height h in feet
A	Slope of saturated vapor pressure curve of air at absolute temperature T_a in °F (mm Hg/°F)
E_P	Computed evaporation (Christiansen method) in mm/day
R	Extra terrestrial radiation in evaporation units (Christiansen method)
C_t	Temperature coefficient

C_w	Wind coefficient
C_h	Relative humidity coefficient
C_s	Percent of possible sunshine coefficient
C_e	Elevation coefficient
T_c	Mean monthly temperature °C
W	Mean windspeed at 2 ft above the ground in Kms/day
H	Mean relative humidity
S	Mean sunshine percentage
E	Elevation in hundreds of meters
u	Monthly consumptive use of crop (in.)
K	Blaney-Criddle coefficient
f	Consumptive use factor
t	Mean monthly temperature in °F
P	Percent of day time hours of the year, occurring during the period
E_{TP}	Potential evapotranspiration between two irrigation interval (by evapotranspirometer)
V_A	Volume of water applied to tank 'A' in the beginning of irrigation interval
V_D	Volume of water supplied by tank 'D' between irrigation interval
V_R	Volume of rainfall between two irrigation interval
V_C	Volume of overflow collected between two irrigation interval
V_F	Volume of runoff collected between two irrigation interval

j	Monthly 'heat index'
J	Yearly 'heat index'
t	Average temperature of any month in °C
t_n	Average monthly temperature of consecutive months of the year in °C (where n = 1, 2, 3, ..., 12)
PE_x	Theoretical potential evapotranspiration for any month with average temperature t°C
PE	Actual computed potential evapotranspiration for the particular month with average temperature t°C
D	Number of days in the month
T	Average number of hours between sunrise and sunset in the month
F.C	Field capacity in moisture content percentage (dry weight basis)
P.W.P	Permanent wilting point (moisture content on dry weight basis)
P_w	Moisture content between field capacity and wilting point in percentage (dry weight basis)
D	Centimeters of water in soil depth (d)
d_b	Bulk density of soil in gms/cc
d_w	Density of water
C_f	Crop factor
H	Accumulated degree-days of maximum daily temperature above 32°F for growing season
U	Consumptive use for the given period.

ABSTRACT

In the present study two phases i.e. evaporation and evapotranspiration have been studied in detail. A correlation has been attempted between evaporation from Class-A pan and that from ordinary can. It is found that good correlation exists between evaporation from ordinary can and Class-A pan.

An evapotranspirometer fabricated in the laboratory and installed at Regional I.A.R.I. Station Kanpur, is used to measure potential evapotranspiration (E_{TP}) for cowpeas during two growing seasons. This measured E_{TP} is compared with values computed by various empirical methods using climatological parameters measured in the field.

The moisture retention curve (0-240 psi) is developed by using pressure membrane extractor. It gives field capacity, permanent wilting percentages and hence available moisture for plants. Actual irrigation schedule in the field is determined by burying three moisture blocks to various depths. Information from the moisture retention curve, evaporation from fully buried can, root depth and crop factors during the growing season is used to develop a simpler technique for the schedule of irrigation. This method can be used by farmers provided crop factors for various crops, for the whole growing season in the region are available.

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Measurement of evaporation and evapotranspiration is of importance in many scientific fields. It is one of the components of the water budget, the knowledge of which is indispensable for the solution of various water management problems. Reliable evaporation data are required for planning, designing and operating reservoirs, ponds, shipping canals, irrigation and drainage systems.

Evapotranspiration data are especially important in semi arid areas like Kanpur where the water which is brought to the field at a great cost must be used in most economical and efficient way. The techniques for the measurement of evaporation and evapotranspiration are still in a developmental stage. In the present study the possibility of utilizing evaporation from simple cans for estimating evapotranspiration and scheduling of irrigation is established. Since it was not possible to deal with various types of crops during this relatively short period, cowpeas (Lobia) which is grown as fodder and pulse crop, is used for measuring potential evapotranspiration.

The capacity of soil to store available water for the use of growing crops is important, because the depth of

water to be applied in each irrigation and frequency of irrigation are both influenced by the storage capacity of soil. A soil moisture retention curve is developed for this purpose.

A large number of empirical methods have been developed for estimation of evaporation from open water surface or potential evapotranspiration from vagetation. With most of these methods the objective has been to use commonly measured meterological elements. The equations developed range from those using simple mean dry-bulb temperature to sophisticated physical relationships which attempt to use all the parameters controlling evaporation.

1.2 Review of Literature

Lysimeter studies were conducted as early as 1688 in France for measurement of percolation losses. For meeting the need of extensive and intensive water management programme, the use of lysimeter increased around 1930.

Non-weighing type lysimeter have been used mainly for studying the effect of constant water table. Patric (1961) used large (3.20 x 6.34 m) non-weighing type lysimeter with field soil on San Dinos experimental forest station, California. For collection of reliable data certain requirements in location, construction and operation of lysimeter are necessary. Makkink (1951) pointed out that the discontinuity in vagetation in and out of the lysimeter

was a major source of error. Small lysimeters with large border permit extra radiation to reach the vagetation with resultent greater evaporation rate.

Popoff (1959) concluded that thermal regime of lysimeter soil be similar to that of the area if its data were to be representative. Measurements of soil water and soil temperature in and out of lysimeter were necessary to determine if the requirements are met.

In 1959 Tanner designed a relatively inexpensive and simple evapotranspirometer 9' x 18' in area and 2' deep. The soil container was placed on vinyl bags filled with water and connected to manometers above ground. The weight of water container was supported by the water pressure in the manometers and changes in the pressure were due to evapotranspiration. The same principle has been used independently by Ekern, Glover, Forsgate (1962), Winter (1962) and Van Bavel in 1964.

Thornthwaite designed an evapotranspirometer for measuring potential evapotranspiration. It consisted of a field tank 4 m^2 in area and 70 cms deep, a water supply and percolation apparatus, a tube to connect field tank, water supply and a water regulating mechanism which is a simple float device to control the water level in tank within one cm. Evapotranspiration was obtained as the difference between water added to the tank and the percolation plus rainfall (if any).

Mather (1954) described a modification in which soil filled tank was connected at a hole in the base to a tube. The tube, sloping slightly downward, terminates inside a cylinder containing a vessel for collecting percolated water. A layer of gravel was placed at the bottom of the tank. The tank was then filled with soil to the level of surrounding ground. The tank was irrigated from above several times a day by known quantities of water so that percolation occurs.

Gilbert and Van Bavel (1954) proposed a simplification of Mather's design. A coarse copper screen was supported nine inches above the tank bottom, leaving a space for collection of the percolated water. A steel pipe one inch in diameter extended to the bottom of the tank, providing an opening through which the water level could be measured with a dipstick. The accuracy of measurements was 0.05 in. Daily readings of water level at the bottom of tank were taken. When the water rose too high at the bottom it was pumped out by a simple handpump and measured. Evapotranspiration was computed as the amount of water added by irrigation plus rainfall (if any) from which was subtracted the change in the water level at the bottom of the tank during the period and water pumped out.

The simple evapotranspirometer was described by Slatyer and Mcllroy (1961) in which a tube is made to rest on the lowest point of a shallow slopping concrete floor.

McIlroy and Angus (1963) for several months compared evapotranspiration from grass under heavy watering from a fibrocement tank with walls 2 cm thick, with that from two ferro-concrete lysimeters of the same external dimensions, but having walls 8 cm thick. In both cases the outer tank wall was 8 cm thick, the gap between inner and outer tanks 7 cm and the depth 110 cm. The conclusion was that under the conditions of experiment the wall thickness effect was not very important.

1.3 Scope of the Present Work

The objective of the present study is:

(i) To measure evaporation & potential evapotranspiration

(ii) To estimate evaporation and evapotranspiration by various empirical methods and to develop some useful concept which can be reliably used.

(iii) To develop moisture retention curve for the full range of growth

(iv) To develop simplified technique for scheduling irrigation

(v) To study the hysteresis effect in soil.

CHAPTER 2

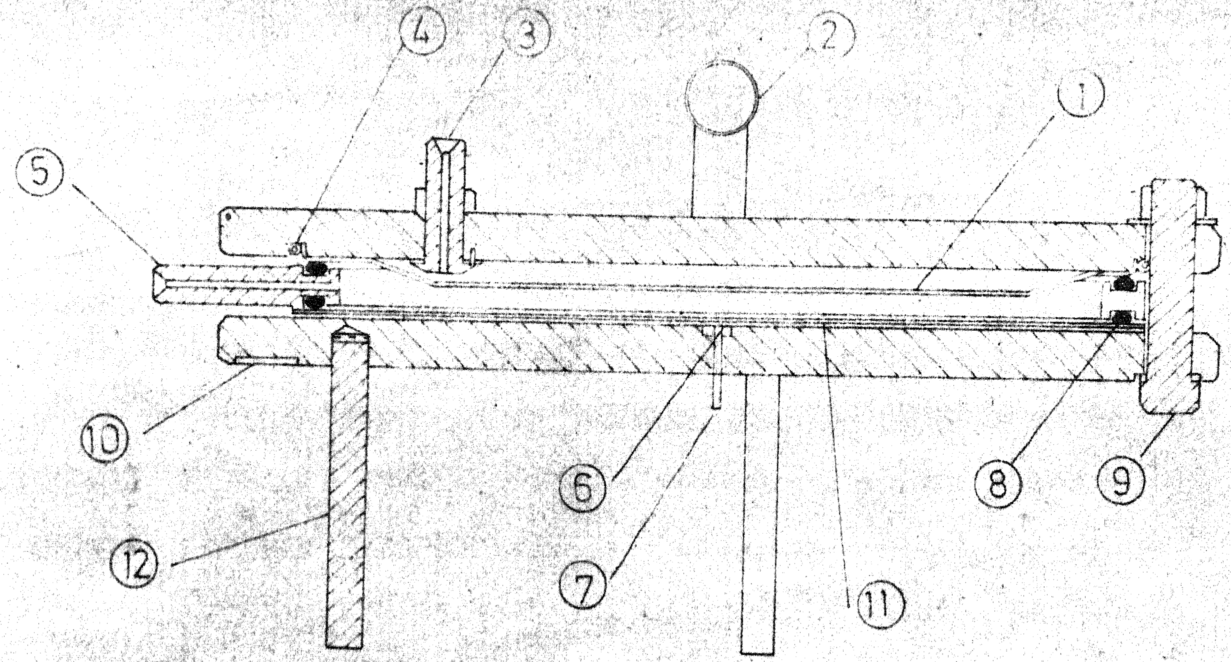
APPARATUS USED FOR THE STUDY

2.1 Pressure Membrane Extractor

The pressure membrane extractor is a versatile tool in the soils laboratory. It makes possible the study of the physical properties of soil not possible by other means. It is adaptable to undisturbed soil cores as well as prepared soil samples.

The moisture retention curve can be developed by this apparatus particularly in the higher range of soil suction. The sectional view is shown in fig. 1 and various parts are itemized (11). It consists of top and bottom plates along with outer cylinder. Top and bottom plates are held together with eight clamping bolts around the periphery of the units. The bolts have special rectangular heads which fit into a constraining groove in the bottom of lower plate. The seal between the top plate and outer cylinder is made by a rubber 'O' ring which fits into a groove in the cylinder wall. A similar 'O' ring makes a seal between the cylinder and screen drain plate.

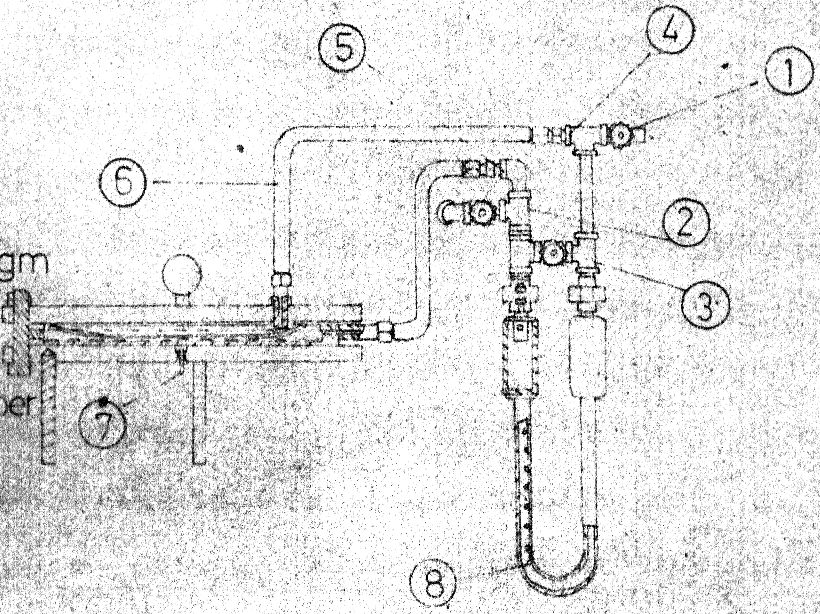
The outer cylinder is held down by the two eccentric headed screws which fit into the slots in the side of the cylinder wall.



① Compressing diaphragm
② Handle
③ Diaphragm chamber inlet
④ " clamping tube
⑤ Extraction chamber inlet
⑥ Screen drain plate
⑦ Outflow tube
⑧ 'O' Ring seals
⑨ Clamping bolt
⑩ Constraining groove
⑪ Cellulose mounted above screen during a run
⑫ Leg

FIG 1 SECTION VIEW OF PRESSURE MEMBRANE EXTRACTOR

① Inlet valve
② Exhaust valve
③ By-pass valve
④ Outlet "2" diaphragm chamber
⑤ Outlet "1" extraction chamber
⑥ Connecting hose
⑦ Outflow tube
⑧ Mercury



FIG·2 ACTION OF THE MERCURY DIFFERENTIAL REGULATOR

Torque wrench and socket are used to tighten the clamping bolts on the extractor. The socket size is 15/16" (2.4 (2.48 cm). A torque of 3-5 ft-lbs (0.415-0.695 Kg meter) as read out on the scale of torque wrench is sufficient for making the pressure seal.

In order to work efficiently, a special hinge called PM hinge is used. By tying the top and bottom plates of the extractor together and by counteracting the weight of the top plate, the PM hinge eliminates the hazard of lifting and handling heavy parts.

It requires a source of regulated air pressure of 220 psi or more in order to extract moisture from soil samples through wilting point and a compressor is utilized for this purpose. Regulation of air supply to the extractor is carried out through proper pressure control manifolds. The clay soil shrinks away from cellulose membrane as moisture is removed from the samples. The mercury differential regulator provides the differential in pressure necessary to force the compressing diaphragm with cellulose membrane. The fig. 2 illustrates how this is accomplished. The gas pressure on the right side of the U-tube, pushes the mercury up in the opposite side of the tube until air bubbles past the bend in the U-tube, as shown. Thus the pressure at outlet '1' is always lower than at outlet '2' by the height of mercury column. This height is adjusted to correspond to approximately 4 psi. By connecting outlet '2' behind the compressing

diaphragm, and outlet '1' to the soil chamber, a pressure differential of 4 psi can always be maintained behind the compressing diaphragm regardless of the extracting pressure.

For general use in the study of water relationship in soils, cellulose membranes are used in the pressure membrane extractor. This material is a regenerated cellulose sheet with average pore radius of 24 Å.

2.2 Volumetric Porous (Pressure) Plate Apparatus

The pressure plate unit, shown in fig. 3, consists of a base containing the porous plate, a ring and an enclosing cylinder or cap. The pressure seal of the ring with the porous plate is maintained by five 8 by 32 screws in which the screw is half in the ring and half in the base. Air is introduced either through the ring or capping cylinder.

A schematic diagram of the entire apparatus is shown in fig. 4. A "Nullmatic" pressure regulator maintains a constant air pressure within the chamber. A constant discharge head is maintained by discharging liquid into or taking up liquid from a horizontal glass tube of small diameter (volume ballast). The level of the volume ballast may be set at the top of the porous plate or adjusted to midpoint of sample. Liquid volume readings are obtained at the burrette after setting the liquid meniscus in the ballast tube to a level mark at the turned end and then reading the volume in the vertical burrette. The meniscus

(1) Steel cylinder (cap)
(2) Weld
(3) 1/4 X 20 Bolt
(4) Brass ring 8 by 32
(5) Neoprene
(6) Gaskets
(7) Plate discharge
(8) Porous plate
(9) Air inlet
(10) Plate discharge
(11) Brass base

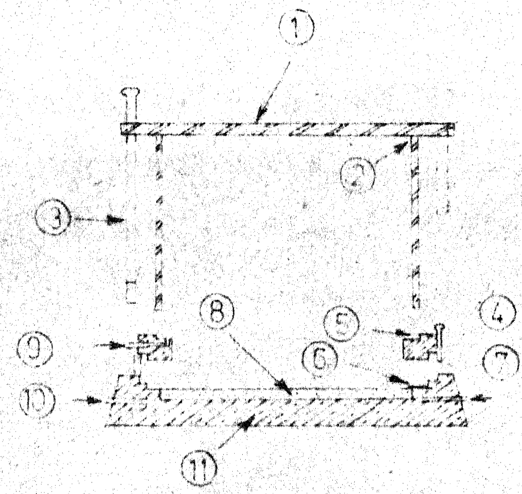
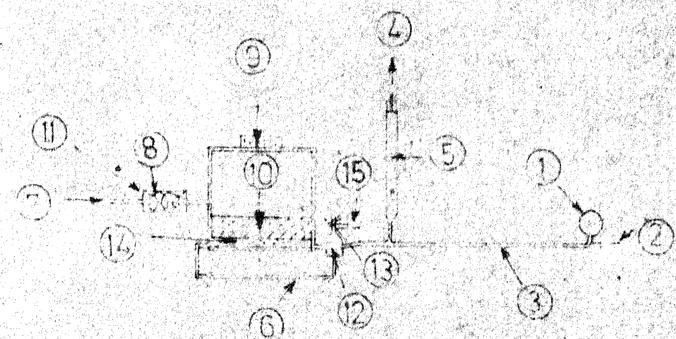


FIG. 3 PRESSURE PLATE UNIT



(1) Plastic bag
(2) Level mark
(3) Volume ballast tube
(4) To airaspirator
(5) Burette
(6) Tubing connection
(7) Regulated pressure
(8) Wick
(9) Aluminum block Containing 3 Watt heater
(10) Soil
(11) Vapor saturator
(12) Air trap
(13) Stopcocks
(14) Porous plate
(15) Level mark

FIG. 4 SCHEMATIC DIAGRAM OF ENTIRE APPARATUS

position in the ballast tube is adjusted by raising the liquid level in the burrette using suction pump or by allowing the liquid to flow from the burrette to the ballast tube under gravity.

Fluctuation in room temperature caused condensation on the inside steel walls of the pressure chamber producing error in liquid measurement. This is prevented by using a 3-watt, 12 volt A.C. or D.C. heater on the top of steel cylinder. The required voltage is obtained by using step down transformer.

Air accumulation directly under the porous plate introduces errors in the liquid volume uptake (on decreasing pressure). In order to remove this defect, an air trap which can be set at an indicated volume is placed between the unit and burrette.

Regulated air pressure to the porous plate is supplied from compressor by manifolds and necessary valve fittings. Liquid losses from the system are minimized by passing air from the regulator through a vapor saturator and by sealing the discharge end with plastic bag.

2.3 Tensiometer and Soil Moisture Block

2.3.1 Tensiometer:

Tensiometers work on the principle that a partial vacuum is created in a closed chamber when water moves out through a porous ceramic tip to the surrounding soil.

Tension is measured with Bourdon vacuum gauge. It consists essentially of a tube, sealed at one end by a porous ceramic cup which is in contact with the soil. The other end of tube is above the ground and is connected to a vacuum gauge. This end of the tube is sealed with a removal cap after the tube has been filled completely with water. Bourdon gauge scale is graduated from 0-100 centibar. Full scale represents 100 centibars (1 bar) of soil suction. Due to the physical properties of free water, all tensiometer can be used reliably only in the 0-85 centibar range of soil suction.

Tensiometers are useful in sandy soils, where this (0.85 bar) represents a major portion of available water, or for crops of high yielding varieties which require frequent irrigation. In the present study tensiometer is utilized for the field calibration of moisture blocks up to 0.85 bar suction and to schedule irrigation during germination period.

2.3.2 Soil Moisture Block:

It uses the principle that a change in moisture content produces a change in some electrical property of the soil or of an instrument in the soil. It consists of two electrodes permanently mounted in conductivity units (gypsum block). Electrodes in the block are attached by wires to a resistance or conductance meter that measures changes in electrical resistance in the block. When the units are buried

in the soil, they become almost a part of the soil and respond to changes in soil-moisture content. Since the amount of moisture in the blocks determines electrical resistance, measurement of any change of resistance is an indirect measure of soil moisture if the block is calibrated for a particular soil.

2.4 Evapotranspirometer

The evapotranspirometer used for measuring potential evapotranspiration is very similar to that of Thornthwaite (16). The water table is maintained at the same level throughout the whole range of growth. The schematic diagram is shown in fig. 5. It consists of field tank (G.I. Sheet) of dimensions 5'x5'x2.5' (152.5x152.5x76 cm) and other tank 2'x2'x3! (61x61x91.5 cm) which houses two small tanks. Tank 'B' is equipped with a float valve which maintains a constant water level in tank 'A'. Tank 'C' collects overflow from tank 'B'. The supply tank 'D' is kept over the stand at an elevated ground floor. The tank 'A' and 'B' are buried in the soil and connected together with a plastic tube of ½" (1.27 cm) diameter. The bottom 3" (7.5 cm) of tank 'A' is filled with gravel and tube coming from 'B' goes inside up to 2 ft (61 cm). The end is wrapped with 50 gauge mesh to avoid blocking due to soil particles. Tank 'A' is filled with soil to the level of surrounding ground. To ensure constant water level, a

NOTE : All dimensions are in cm

A - FIELD TANK
B - FLOAT VALVE TANK
E - HOUSING TANK
C - OVERFLOW COLLECTION TANK
D - SUPPLY TANK ϕ=61 CM
F - RUN OFF COLLECTION TANK ϕ = 36 CM

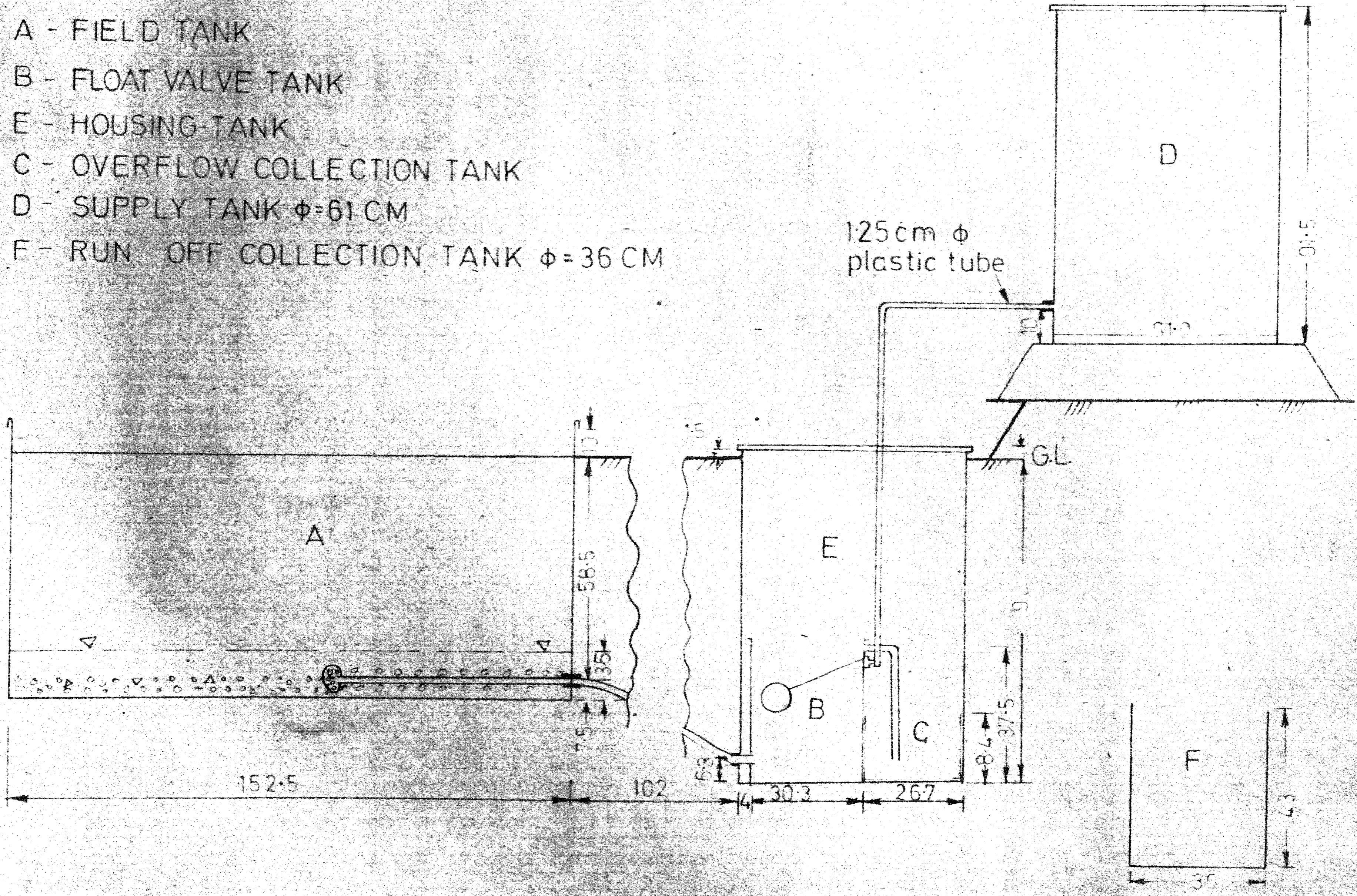


FIG. 5 EVAPOTRANSPIROMETER FOR ESTIMATING POTENTIAL EVAPOTRANSPIRATION

moisture block is buried to a depth of 2 ft (61 cm) and readings taken daily.

In order to estimate runoff during rainy days, another tank of 36 cm diameter is used near tank 'A'. The soil from all the four sides of field tank is given a slope and the runoff is led into buried tank through a channel. The amount of precipitation falling in the channel and tank is taken care of during calculation.

2.5 Instruments Used to Measure Meterological Parameters and Evaporation

In order to measure evaporation, Class-A pan (Standard US Weather Bureau Evaporation Pan) and ordinary cans are utilized. The various dimensions of Class-A pan are shown in fig. 6. The measurements of evaporation are made with sliding gage.

Five ordinary cans of 17.5 cm diameter and 19.5 cm height, with varying depth inside the soil are used to measure evaporation. All of them are painted from inside to prevent rusting and thus affecting evaporation measurements.

Rainfall is measured with a non-recording rain gage. The temperature and relative humidity are measured with thermohygrograph which gives continuous record on a graph sheet for 24 hours. To measure wind speed cup type anemometer is used.

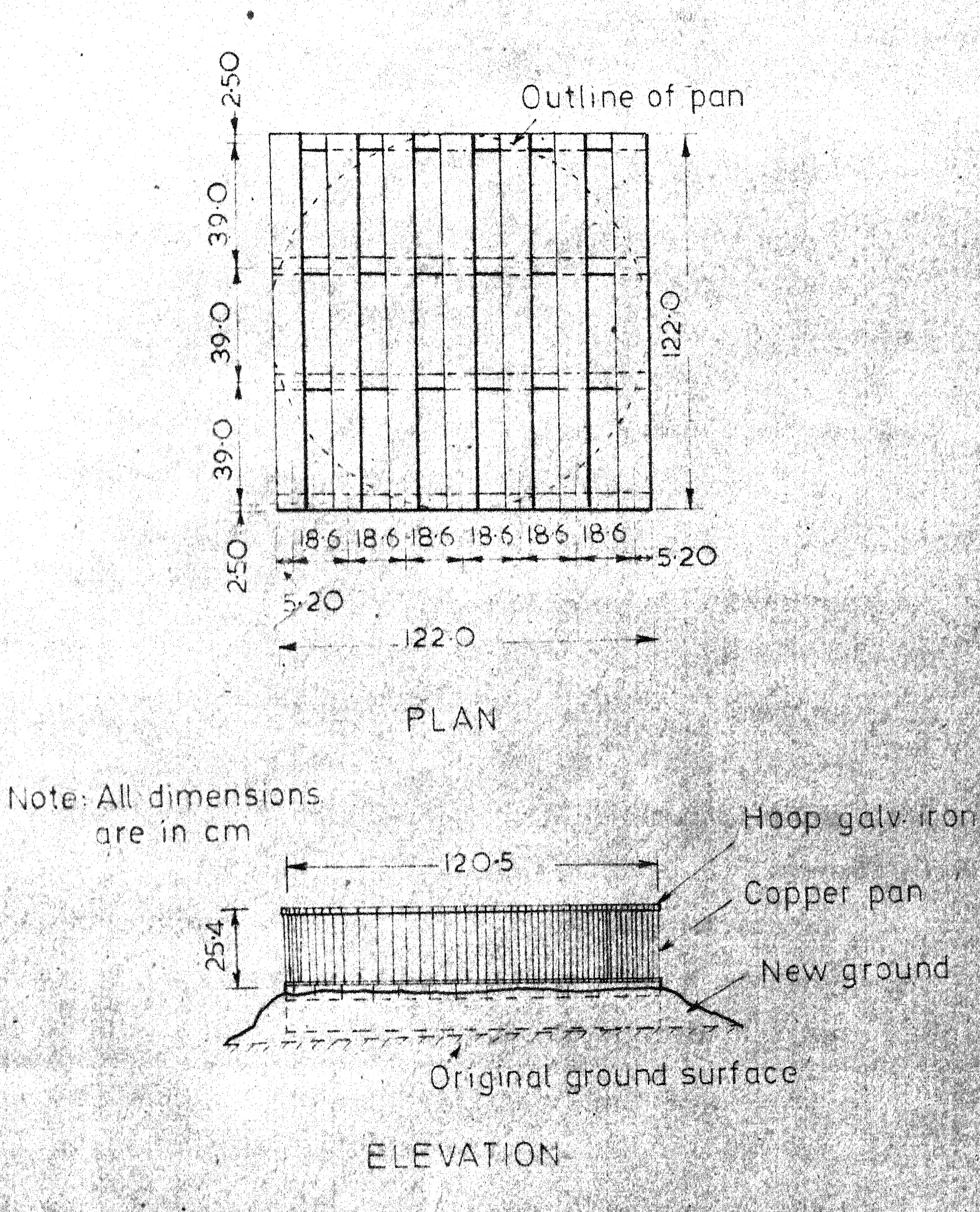


FIG. 6 STANDARD WEATHER BUREAU CLASS-A EVAPORATION PAN

CHAPTER 3

EMPIRICAL METHODS FOR ESTIMATING EVAPORATION AND EVAPOTRANSPIRATION

3.1 Penman Method

How temperature, humidity, wind velocity, vapor pressure and solar radiation influence consumptive use has been studied by several research workers. Penman, in England, has made the most complete analysis using several climatic variables, whereas temperature has been used as principal variable to obtain an index to consumptive use by Thornthwaite in humid eastern United States. Lowry and Johnson, and Blaney-Criddle in the arid Western States, used both temperature and percentage of day time hours.

Penman (10) has made the most complete theoretical approach, showing that consumptive use is inseparably connected to incoming solar radiation. His formula representing the potential evapotranspiration is as follows:

$$E_T = \frac{AH + 0.27E_a}{A + 0.27} \qquad (1)$$

where

$$H = R_A(1-r)(0.18+0.55\,\tfrac{n}{N}) - \sigma T_a^4(0.56-0.92\sqrt{e_d}).$$
$$(0.10+0.90\,\tfrac{n}{N}) \qquad (2)$$

$$E_a = 0.35(e_a - e_d)(1+0.0098u_2) \tag{3}$$

Wind measurements taken at other height can be corrected to the 2-meter elevation by use of the formula

$$u_2 = u_1\left(\frac{\log 6.6}{\log h}\right) \tag{4}$$

Using Penman method potential evapotranspiration has been calculated for the two growing seasons. A sample calculation is given below.

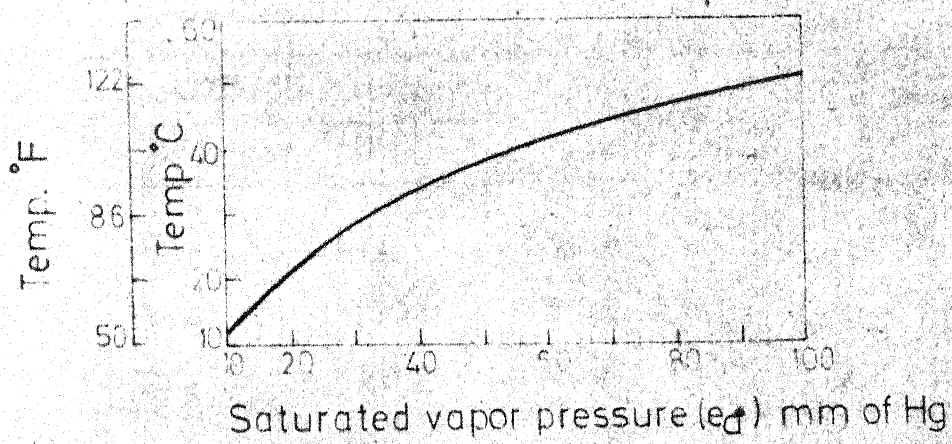
SAMPLE CALCULATION OF POTENTIAL EVAPOTRANSPIRATION BY PENMAN METHOD

All the data are collected at Regional I.A.R.I. Station, Kanpur

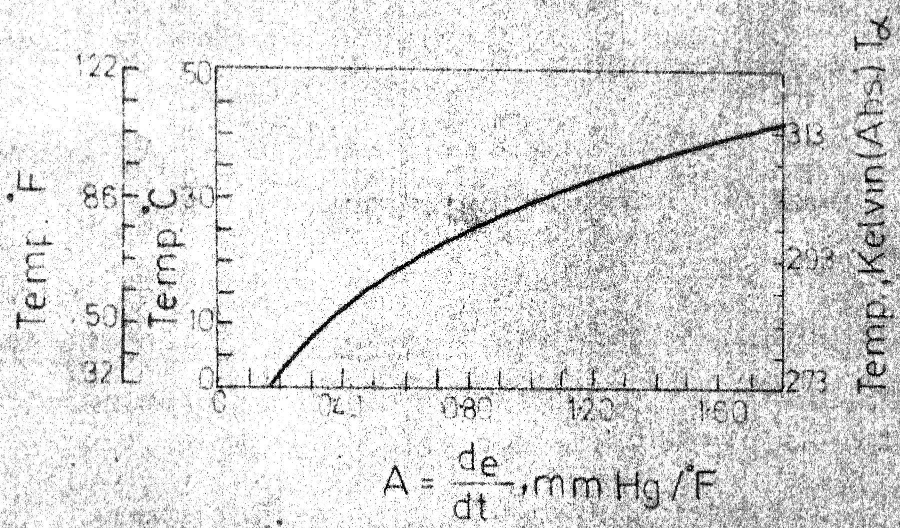
A. Data

1	Month	March
2	Sunshine n/N	88%
3	Temperature	73.4°F
4	Windspeed u_1	163.0 Km/day (collected at 4 ft above ground surface)
	u_2	$\frac{163.0}{1.61}\left(\frac{0.8195}{0.6021}\right) = 137.5$ Miles/day (at 2 meter above ground surface)
5	Radiation rate R_A (see Table 1)	13.2
6	Reflection coefficient 'r' – %	30
7	Relative humidity – %	61.5

B.	Solving expression: $R_A(1-r)(0.18+0.55\ \frac{n}{N})$	
8	$(1-r)$	0.70
9	$(0.18+0.55\ \frac{n}{N})$	0.67
10	Item 5 x item 8 x item 9	6.2
C.	Solving expression: $\sigma T_a^4(0.56-0.092\sqrt{e_d})(0.10+0.90\ \frac{n}{N})$	
11	Vapor pressure	
	a) Saturated, e_a (see fig. 7)	24
	b) Actual, $e_d = (R.H \times e_a)$	14.7
	c) $\sqrt{e_d}$	3.81
12	σT_a^4 (see Table 2)	15.50
13	$(0.56-0.092\sqrt{e_d})$	0.21
14	$(0.10+0.90\ \frac{n}{N})$	0.89
15	Item 12 x item 13 x item 14	2.90
D.	Solving for H	
16	Item 10 - item 15	3.3
E.	Solving for $E_a = 0.35(e_a-e_d)(1+0.0098u_2)$	
17	$0.35(e_a-e_d)$	3.26
18	$(1+0.0098u_2)$	2.35
19	Item 17 x item 18	7.65
F.	Solving for $E_T = (AH + 0.27E_a)/(A + 0.27)$	
20	A (see fig. 7)	0.78
21	AH	2.57
22	$0.27E_a$	2.10
23	A + 0.27	1.05
24	E_T	4.45



TEMPERATURE Vs SATURATED VAPOR PRESSURE
(AFTER CRIDDLE)



TEMPERATURE Vs A

FIG.7

TABLE 1

Intensity of Solar Radiation (R_A) mm of Water

Degree North Lattitude					Month
40°	30°	20°	10°	0°	
6.0	8.5	10.8	12.8	14.5	January
8.3	10.5	12.3	13.9	15.0	February
11.0	12.7	13.9	14.8	15.2	March
13.9	14.8	15.2	15.2	14.7	April
15.9	16.0	15.7	15.0	13.9	May
16.7	16.5	15.8	14.8	13.4	June
16.3	16.2	15.7	14.8	13.5	July
14.8	15.3	15.3	15.0	14.2	August
12.2	13.5	14.4	14.9	14.9	September
9.3	11.3	12.9	14.1	15.0	October
6.7	9.1	11.2	13.1	14.6	November
5.5	7.9	10.3	12.4	14.3	December

TABLE 2

Values of σT_a^4 for Various Temperatures

Temperature	σT_a^4
° Abs	mm H_2O/day
270	10.73
275	11.51
280	12.40
285	13.20
290	14.26
295	15.30
300	16.34
305	17.46
310	18.60
315	19.85
320	21.15
325	22.50

TABLE 3

Estimation of Daily Potential Evapotranspiration by Penman Method

Month	Average Temp. °C	Relative Humidity (%)	Windspeed u_2 (Miles/day)	Radiation rate (R_A) mm H_2O/day	(E_a) mm/day	Evapotrans-piration mm/day (E_T)	Consumptive use from Evapotrans-pirometer mm/day
1974 August	29.05	85.21	105	15.3	3.60	2.90	2.10
September	29.23	92.18	86	13.8	3.50	3.80	3.44
October	27.20	77.68	74	11.9	4.50	3.14	3.30
November	19.93	71.45	48	9.8	2.78	2.10	2.06
December	14.82	76.03	49	8.7	1.84	1.50	1.92
1975 February	16.41	72.50	97	11.1	3.50	2.60	1.25
March	23.00	61.50	138	13.2	7.65	4.45	2.18
April	30.50	57.50	181	14.9	11.10	5.65	8.50
May	33.47	50.59	146	15.9	17.20	7.15	10.00

Table 3 compares the computed values of potential evapotranspiration (consumptive use) with the measured values of consumptive use in field.

3.2 Christiansen Method

In recent years, much work has been done on correlating evapotranspiration with evaporation as measured in an evaporimeter. Christiansen provided an empirical formula to permit the estimation of pan evaporation from climatic data when reliable measured pan evaporation is not available. Christiansen (17) developed the following pan evaporation equation.

$$E_P = 0.459 \, RC_tC_wC_hC_sC_e \tag{5}$$

where

$$C_t = 0.393 + 0.02796T_c + 0.0001189T_c^2 \tag{6}$$

$$C_w = 0.708 + 0.0034W - 0.0000038W^2 \tag{7}$$

$$C_h = 1.250 - 0.0087H + 0.75\text{x}10^{-4} \, H^2 - 0.85\text{x}10^{-8} \, H^4 \tag{8}$$

$$C_s = 0.542 + 0.0080S - 0.78\text{x}10^{-4} \, S^2 + 0.62\text{x}10^{-6} \, S^3 \tag{9}$$

$$C_e = 0.970 + 0.00984E \tag{10}$$

Using Christiansen method evaporation has been calculated for the growing seasons. A sample calculation is as follows

SAMPLE CALCULATION FOR ESTIMATING EVAPORATION
BY CHRISTIANSEN'S FORMULA

Location: I.A.R.I. Regional Station Kanpur

Latitude: 26° 31' N

Altitude: 417.5 ft

Month: July

Mean temperature: 30.1°C

Windspeed at 4 ft: 158.5 Km/day

at 2 ft $158.5 \times (\frac{2}{4})^{\frac{1}{4}} = 133$ Km/day

Mean relative humidity: 81.37%

Sunshine percentage: 17.5%

R for July, Latitude 26° 31' N (see Table 1) = 520.21 mm

$$C_t = 0.393 + 0.02796T_c + 0.0001189T_c^2 \qquad T_c = {}^\circ C$$
$$= 1.339$$
$$C_w = 0.708 + 0.0034W - 0.0000038W^2$$
$$= 1.090$$
$$C_h = 1.250 - 0.0087H + 0.75\times10^{-4}\ H^2 - 0.85\times10^{-8}\ H^4$$
$$= 0.670$$
$$C_s = 0.542 + 0.0080S - 0.78\times10^{-4}\ S^2 + 0.62\times10^{-6}\ S^3$$
$$= 0.662$$
$$C_e = 0.970 + 0.00984E$$
$$= 0.983$$
$$E_P = 0.459\ RC_tC_wC_hC_sC_e$$
$$= 0.459\times520.21\times1.339\times1.090\times0.670\times0.662\times0.983$$
$$= 151.0$$
$$= 4.86 \text{ mm/day}$$

TABLE 4

Estimation of Evaporation by Christiansen Method

Month	Mean Temp. °C	Wind Speed Km/day at 2'	% RH	Sun-shine % 'S'	'R' mm/month	'C_t'	'C_w'	'C_h'	'C_s'	'C_e'	E_p Monthly (mm)	E_p Daily (mm)	Class-A Pan Evapo-ration (mm)
1974 July	30.10	133.0	81.37	17.5	520.21	1.339	1.090	0.670	0.662	0.983	151.0	4.86	4.59
Aug.	29.05	104.0	85.21	25.0	495.62	1.305	1.018	0.607	0.703	0.983	127.1	4.10	4.01
Sept.	29.23	85.0	82.18	70.0	431.80	1.310	0.969	0.656	0.932	0.983	151.04	5.05	4.70
Oct.	27.20	69.0	77.68	70.0	378.40	1.243	0.924	0.720	0.932	0.983	131.0	4.24	4.44
Nov.	19.93	47.5	71.45	80.0	305.22	0.998	0.861	0.791	1.000	0.983	93.5	3.12	3.30
Dec.	14.82	48.5	76.03	80.0	285.72	0.830	0.864	0.738	1.000	0.983	68.0	2.20	2.30
1975 Jan.	13.58	89.0	82.63	85.0	300.60	0.795	0.978	0.657	1.039	0.983	73.4	2.44	2.28
Feb.	16.41	96.0	72.50	85.0	306.60	0.882	0.998	0.779	1.039	0.983	98.5	3.51	3.41
March	23.00	137.0	61.50	88.0	419.87	1.100	1.100	0.876	1.064	0.983	213.0	6.85	6.14
April	30.50	176.0	57.50	88.0	462.70	1.342	1.185	0.905	1.064	0.983	318.0	10.6	9.75
May	33.47	145.0	50.59	88.0	512.80	1.465	1.118	0.947	1.064	0.983	401.0	12.9	11.40

Table 4 compares the computed values of evaporation and Class-A pan evaporation measured in the field.

3.3 Blaney-Criddle Method

Blaney-Criddle (10) developed a simplified formula using temperature and day time hours for the arid western portion of the United States.

$$u = Kf \tag{11}$$

$$f = \frac{t \times p}{100} \tag{12}$$

The consumptive use of water by a particular crop in some areas being known, an estimate of the use by the same crop in some other area may be made by application of above formula. Using Blaney-Criddle method, coefficient 'K' has been calculated for the growing season. A sample calculation is given below:

SAMPLE CALCULATION OF 'K' BY BLANEY-CRIDDLE METHOD

Location: Regional I.A.R.I. Station Kanpur

Month: August

Mean temperature: 84.21°F

Percentage 'p' of day time hours of the year, occurring during the period (see Table 5) 9.13

Consumptive use factor 'f' $= \frac{t \times p}{100}$

$$= \frac{84.21 \times 9.13}{100} = 7.70$$

TABLE 5

Percent Day-Light Hours

Month	Latitude 0° North							
	0	5	10	15	20	25	30	32
January	8.50	8.32	8.13	7.94	7.74	7.53	7.30	7.20
February	7.66	7.57	7.47	7.36	7.25	7.14	7.03	6.97
March	8.49	8.47	8.45	8.43	8.41	8.39	8.38	8.37
April	8.21	8.29	8.37	8.44	8.52	8.61	8.72	8.76
May	8.50	8.65	8.81	8.98	9.15	9.33	9.53	9.62
June	8.22	8.41	8.60	8.80	9.00	9.23	9.49	9.59
July	8.50	8.67	8.86	9.05	9.25	9.45	9.67	9.77
August	8.49	8.60	8.71	8.83	8.96	9.09	9.22	9.27
September	8.21	8.23	8.25	8.28	8.30	8.32	8.33	8.34
October	8.50	8.42	8.34	8.26	8.18	8.09	7.99	7.95
November	8.22	8.07	7.91	7.75	7.58	7.40	7.19	7.11
December	8.50	8.30	8.10	7.88	7.66	7.42	7.15	7.05

TABLE 6

Table Showing the Potential Evapotranspiration Measured by Evapotranspirometer

Period	Amount of Water Spplied Over Field Tank 'A' (cu.ft)	Amount Supplied by Tank 'D' (cm)	Rain-fall 'R' (mm)	Runoff 'E' (cm)	Over-flow 'C' (cm)	Potential Evapotranspiration for the period (A+D+R-F-C) (mm)
July 28-Aug 2,1974	0.46	-	1.20	-	-	6.83
Aug 3-Sep 6 "	1.45	-	81.70	30.43	60.10	80.30
Sep 7-Sep 21 "	4.60	-	8.60	13.80	3.80	58.35
Sep 22-Nov 12 "	5.0	25.80	126.70	90.40	100.60	168.70
Nov 13-Dec 3 "	2.40	8.30	-	-	4.25	38.85
Feb 13-Feb 17,1975	0.20	-	4.77	6.55	10.80	3.12
Feb 18-Mar 2 "	1.32	1.85	-	-	10.58	17.20
Mar 3-Mar 11 "	1.70	3.20	-	-	6.35	24.30
Mar 12-Mar 22 "	2.58	4.60	-	-	8.45	36.30
Mar 23-Apr 2 "	3.20	7.80	7.40	10.30	15.40	45.93
Apr 3-Apr 10 "	3.78	19.40	-	-	19.10	68.40
Apr 11-Apr 20 "	4.25	29.50	-	-	5.30	88.30
Apr 21-May 1 "	4.95	33.20	-	-	15.90	100.40
May 2-May 11 "	4.90	34.40	-	-	10.61	101.60
May 12-May 21 "	4.87	32.10	-	-	7.40	98.90

TABLE 7

Table Showing the Variation of Crop Factor with Growing Season

Period	Consumptive Use (mm)	Evaporation from Class 'A' Pan (mm)	Crop Factor 'K'
1974			
Jul 21-Aug 2	6.83	24.90	0.274
Aug 3-Sep 6	80.30	161.20	0.530
Sep 7-Sep 21	58.35	79.60	0.732
Sep 22-Nov 12	168.70	207.60	0.815
Nov 13-Dec 3	38.85	61.00	0.635
1975			
Feb 13-Feb 17	3.12	19.60	0.160
Feb 18-Mar 2	17.20	44.10	0.390
Mar 3-Mar 11	24.30	52.00	0.470
Mar 12-Mar 22	36.30	70.0	0.520
Mar 23-Apr 2	45.97	71.50	0.645
Apr 3-Apr 10	68.40	81.00	0.830
Apr 11-Apr 20	88.30	88.80	1.000
Apr 21-May 1	100.40	116.10	0.860
May 2-May 11	101.60	106.00	0.960
May 12-May 21	98.9	113.10	0.875

TABLE 8

Table Showing Values of Blaney-Criddle
Coefficient 'K' for Various Months

Month	Mean Monthly Temperature °F (t)	Day Time Hours % (P)	Consumptive Use Factor (f)	Approximate Consumptive Use (u) (in.)	Coefficient (K)	Crop Factor C_f
1974						
Aug.	84.21	9.13	7.70	2.60	0.340	0.50
Sept.	84.60	8.32	7.05	4.05	0.575	0.75
Oct.	81.10	8.06	6.55	4.10	0.625	0.73
Nov.	67.80	7.36	4.98	2.80	0.560	0.63
1975						
Feb.	61.60	7.11	4.40	1.39	0.316	0.34
March	73.50	8.39	6.16	4.10	0.665	0.58
Apr.	86.90	8.65	7.50	10.05	1.400	0.88
May	92.20	9.40	8.68	11.80	1.360	0.93

Approximate consumptive use for August month (see Table 6)

$$= 2.6 \text{ in.}$$

Coefficient 'K' $= \frac{2.6}{7.70} = 0.340$

Table 8 shows the values of Blaney-Criddle coefficient and crop factor (from Table 7) for various months.

3.4 Thornthwaite Method

C.W. Thornthwaite (19) carried out many experiments in the United States using lysimeters and studied extensively the correlation between temperature and evapotranspiration. From this work he devised a method enabling estimates to be made of the potential evapotranspiration from short, close set vegetation with an adequate water supply.

$$j = \left(\frac{t_n}{5}\right)^{1.514} \tag{13}$$

$$J = \sum_{1}^{12} j \tag{14}$$

$$PE_x = 1.6\left(\frac{10t}{J}\right)^{a} \tag{15}$$

$$a = (675 \times 10^{-9})J^3 - (771 \times 10^{-7})J^2 + (179 \times 10^{-4})J + 0.492 \tag{16}$$

$$PE = PE_x \frac{DT}{360} \tag{17}$$

Using Thornthwaite method evapotranspiration has been calculated for the two growing seasons. A sample calculation is as follows:

SAMPLE CALCULATION FOR POTENTIAL EVAPOTRANSPIRATION BY THORNTHWAITE METHOD

Location: Regional I.A.R.I. Station Kanpur

Monthly 'heat index', j $= (t_n/5)^{1.514}$

Yearly 'heat index' J $= \sum_{1}^{12} j$

$= (14.7+14.5+13.7+10.3+6.5+4.8+5.25+7.9+12.5+16.5+15.3+14.85)$

$= 136.80$

(Note: For the last two months approximate monthly 'heat index' values are assumed).

$$a = (675\text{x}10^{-4})J^3 - (771\text{x}10^{-7})J^2 + (179\text{x}10^{-4})J + 0.492$$

$$= 1.69 - 1.44 + 2.43 + 0.492$$

$$= 3.172$$

Theoretical Potential Evapotranspiration for September month

$$PE_x = 1.6\left(\frac{10t}{J}\right)^a$$

$$= 1.6\left(\frac{10\text{x}29.23}{136.8}\right)^{3.172}$$

$$= 18.20 \text{ cm}$$

Actual Potential Evapotranspiration for **September month** with average temperature t° is given by

$$PE = PE_x \frac{DT}{360} = 18.20\left(\frac{30\text{x}8.4}{360}\right)$$

$$= 12.70 \text{ cm}$$

TABLE 9

Estimation of Monthly Potential Evapotranspiration by Thornthwaite Method

Month	Average Temperature °C	Theoretical Potential Evapotranspiration (PE_x) cm	Corrected (Computed) Potential Evapotranspiration (PE) cm	Measured Potential Evapotranspiration from Evapotranspirometer cm
1974 July	30.10	20.50	5.30	-
August	29.05	17.90	5.10	6.50
September	29.23	18.20	12.70	10.30
October	27.20	14.20	10.30	10.20
November	19.93	5.45	4.38	6.25
December	14.82	2.10	1.75	5.95
1975 February	16.41	2.88	2.28	3.49
March	23.00	8.40	7.60	6.75
April	30.50	20.80	18.10	25.60
May	33.47	29.40	26.60	30.00

Table 9 compares the computed values of E_{TP} with the measured values in the field with evapotranspirometer.

3.5 Lowry-Johnson Method

Lowry-Johnson (6) developed a procedure for estimating water requirements for irrigation projects. A linear relationship is assumed between "effective heat" and consumptive use. Effective heat is defined as the accumulation, in day degrees, of maximum daily growing season temperature above 32°F.

The approximate relationship

$$U = 0.000156H + 0.8 \tag{18}$$

is used in estimating the consumptive use by Lowry-Johnson method. Using this method total consumptive use for two growing season is computed as follows:

Month	Days	Degree days of maximum daily temperature above 32°F
July	4	237
August	31	1772
September	30	1822
October	31	1850
November	30	1513
December	3	138
February	16	685
March	31	1780
April	30	2182
May	21	1600

$$H = 13579$$

$$U = 0.000156H + 0.8$$

$$= 0.000156 \times 13579 + 0.8$$

$$= 2.16 + 0.8 = 2.96 \text{ ft} = 90 \text{ cm}$$

Actual consumptive use for the two growing seasons (from Table 6) $= 94.14$ cm

CHAPTER 4

EXPERIMENTAL WORK

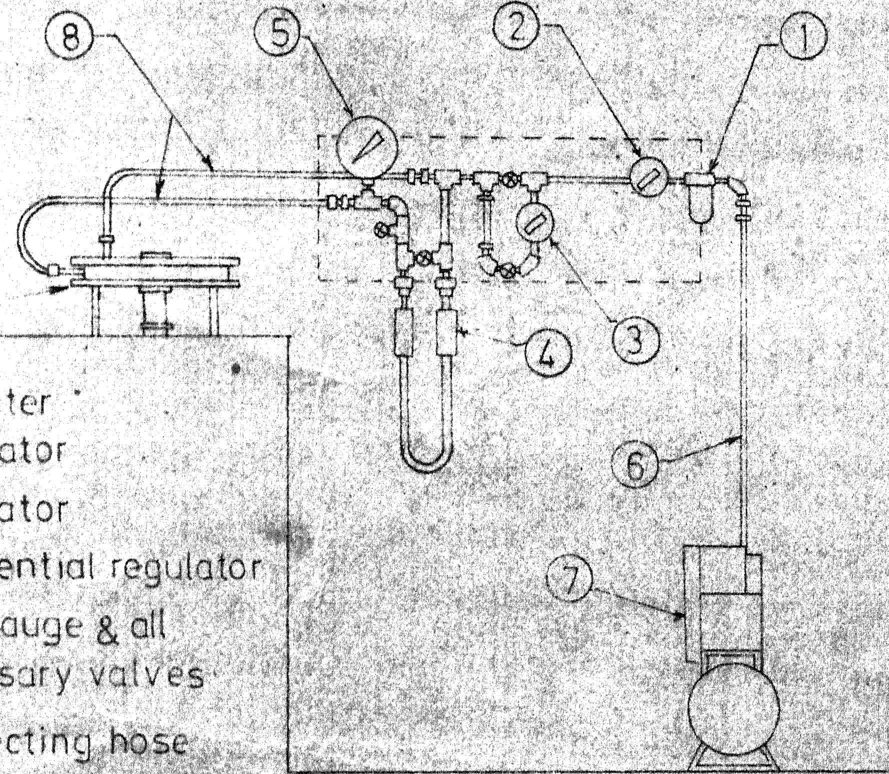
4.1 Laboratory Experiments

4.1.1 Development of Moisture Retention Curve in 0-14 Bar Range Using Pressure Membrane Extractor:

Preparation of Soil Samples: The laboratory set up for moisture retention studies is shown in fig. 8. A soil sample was taken from the field and air dried. It was passed through U.S. Sieve no. 10 (2 mm dia. hole) and a number of small samples weighing 25 gm were prepared. Since the cellulose membrane was dry and stiff it was immersed in water for 10 hours before using. The cellulose membrane was laid on plastic sheet and four sample container rings of size 1 cm high and 5.5 cm dia. were kept over it. The samples were poured out in every container and levelled. They were allowed to stand for 24 hours with excess water on the membrane.

Mounting the Cellulose Membrane: The cellulose membrane together with soil was carefully slid off the plastic plate. In order to keep soil particles away from circular ring seal, a fine cloth was placed just inside the outer cylinder. Excess water from the membrane was removed with a pipet and cotton.

Making a Run: The '0' ring was laid in the top groove of



(1) Air filter
(2) Regulator
(3) Regulator
(4) Differential regulator
(5) Test gauge & all necessary valves
(6) Connecting hose
(7) P M Compressor
(8) Connecting hoses
9 Pressure membrane extractor with P M hinge mounted

FIG. 8 LABORATORY SETUP FOR MOISTURE RETENTION STUDIES USING PRESSURE MEMBRANE EXTRACTOR WITH THE COMPRESSOR AS PRESSURE SOURCE

outer cylinder and the top plate was set so that the top and bottom bolts slots line up. The clamping bolts were inserted and tightened down. The small outflow tube in the screen drain plate was connected to burette through a small diameter plastic tube. The pressure regulator was now opened slowly and adjusted to the extraction pressure of 1.5 psi. Water started flowing immediately into the burette. The level of burette was observed periodically. After few hours, the rate of flow from the soil samples ceased and equilibrium was attained. Now the pressure was raised to 3 psi and above procedure repeated. In the beginning of the run the increment in pressure was small and at later stages when the moisture was held at a greater tension, increment in pressure was accordingly increased.

Mercury differential regulator was applied for pressure greater than 30 psi. At the close of a run, the by-pass valve on the mercury differential regulator was opened first. Immediately thereafter the pressure regulator was shut off and the exhaust valve was opened until whole of the pressure gets released from the extractor. The clamping bolts and top plate were removed and sample was immediately transferred to moisture box. The moisture box was weighed and kept in the oven for 24 hours and percentage of moisture on dry weight basis was calculated. Thereafter the percentage of moisture content at other suction values was determined by back calculations. Table 10 gives

TABLE 10

Tension and Corresponding Burette Readings for Moisture Retention Curve

Tension (psi)	Burette Reading		Percentage of Moisture Content (Dry Weight Basis)	
	Ist Set	IInd Set	Ist Set	IInd Set
0	50.0	30.0	36.75	35.50
1.5	46.85	26.74	33.60	32.48
3.0	43.55	24.26	30.90	30.00
4.5	40.95	21.98	28.30	27.72
6.0	39.80	20.50	27.15	26.24
7.5	37.45	19.76	24.80	25.50
9.0	37.05	19.16	24.40	24.90
12.0	36.15	18.52	23.50	24.26
15.0	35.65	18.00	23.00	23.74
30.0	33.25	15.47	20.60	21.22
60.0	30.35	12.95	17.70	18.70
120.0	27.90	9.05	15.25	14.80
210.0	25.55	6.75	12.90	12.50
240.0	25.40	6.65	12.75	12.40

For IInd Set: At the end weight of wet sample = 20.80 gms

Weight of dry sample = 20.22 gms

Weight of container = 15.50 gms

Percentage of moisture content (dry weight basis)

= 12.40

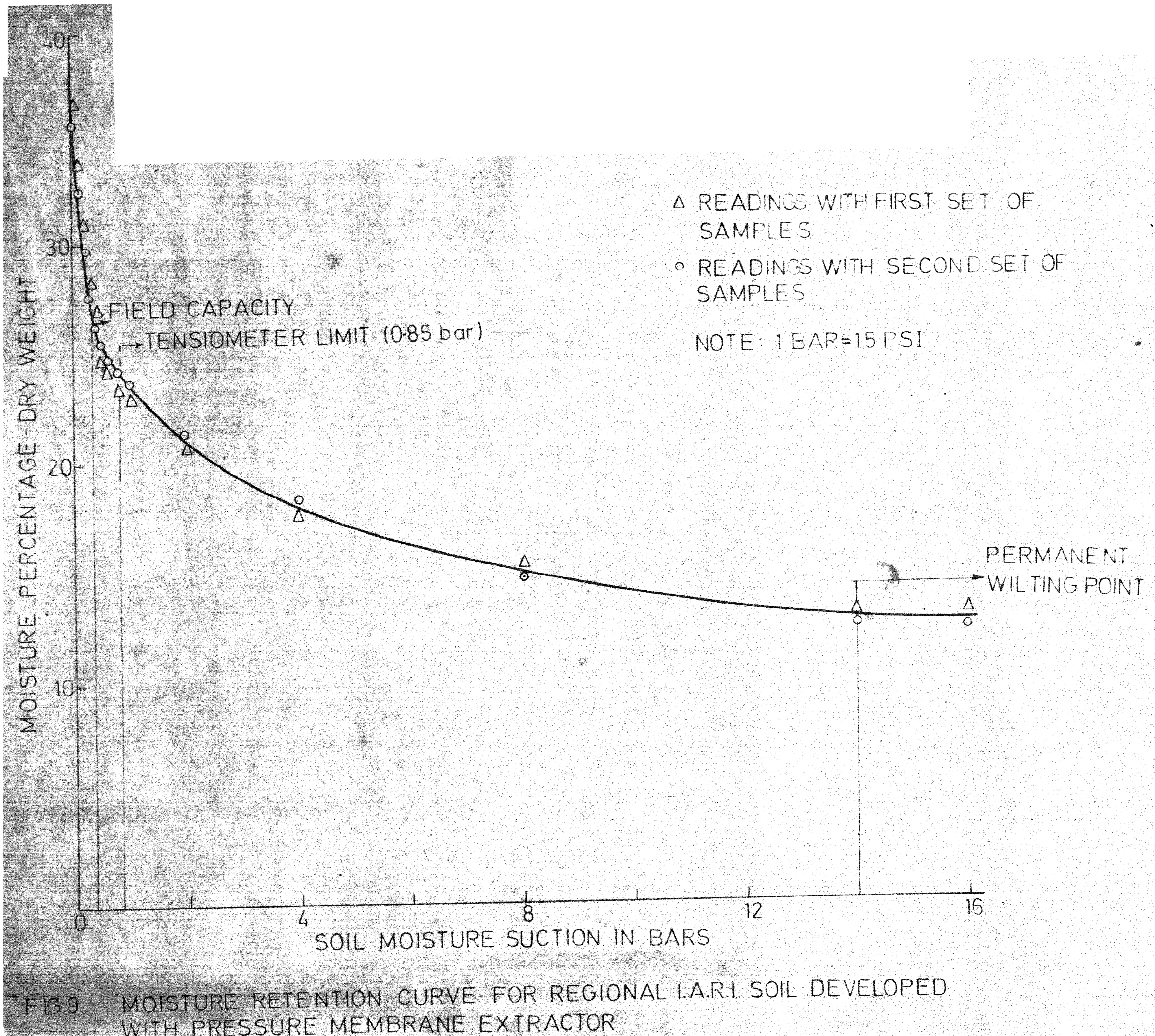


FIG 9 MOISTURE RETENTION CURVE FOR REGIONAL I.A.R.I. SOIL DEVELOPED WITH PRESSURE MEMBRANE EXTRACTOR

the moisture content at various suction values and calculation at the bottom. This procedure was repeated twice and the soil moisture retention curve is plotted as shown in fig. 9.

4.1.2 Development of Hysteresis Loop:

Volumetric porous (pressure) plate apparatus was used with carefully regulated air up to 15 psi (0-1 bar) to obtain precise data on release and uptake of soil moisture from prepared soil samples. Details of laboratory set up are shown in fig. 4. Soil samples were prepared in the same way as in case of soil moisture retention studies. In the present study two samples, each of 25 gm were put over the porous plate into the sample container rings. These samples were allowed to saturate through the capillary action of soil. The pressure inside the pressure plate unit was raised at lower rate in the beginning and higher at the end. Reverse procedure was followed in the reverse cycle. Before increasing or decreasing the pressure in the unit equilibrium, was obtained. A constant discharge head was maintained by discharging liquid into or taking up liquid from a horizontal glass tube (ballast tube). Liquid volume readings were obtained at the burette after setting the liquid meniscus in the ballast tube to a level mark at the turned end. The meniscus position in the ballast tube was adjusted by raising the liquid level with suction pump attached at the open end of burette and by allowing the liquid to flow

TABLE 11

Development of Hysteresis Curve by Volumetric Pressure Plate Extractor

Pressure (bar)*	Burette Reading	Moisture Content % (Dry Weight)	Burette Reading	Moisture Content % (Dry Weight)	Burette Reading	Moisture Content % (Dry Weight)
0.1	22.0	35.5	19.60	30.8	19.6	30.8
0.2	20.5	32.6	18.65	28.9	19.2	30.0
0.3	19.3	30.2	17.60	26.8	18.5	28.6
0.4	18.2	28.0	16.70	25.0	17.5	26.6
0.5	17.4	26.4	16.10	23.8	16.7	25.0
0.6	16.7	25.1	15.70	23.0	16.2	24.0
0.8	15.7	23.0	14.95	21.5	15.8	23.2
1.0	14.8	21.2	14.80	21.2	15.4	22.4

* 1 bar = 15 psi

At the end weight of wet sample = 24.35 gm

Weight of dry sample = 22.715 gm

Weight of container = 15.50 gm

Percentage of moisture content (Dry weight basis)

= 22.40

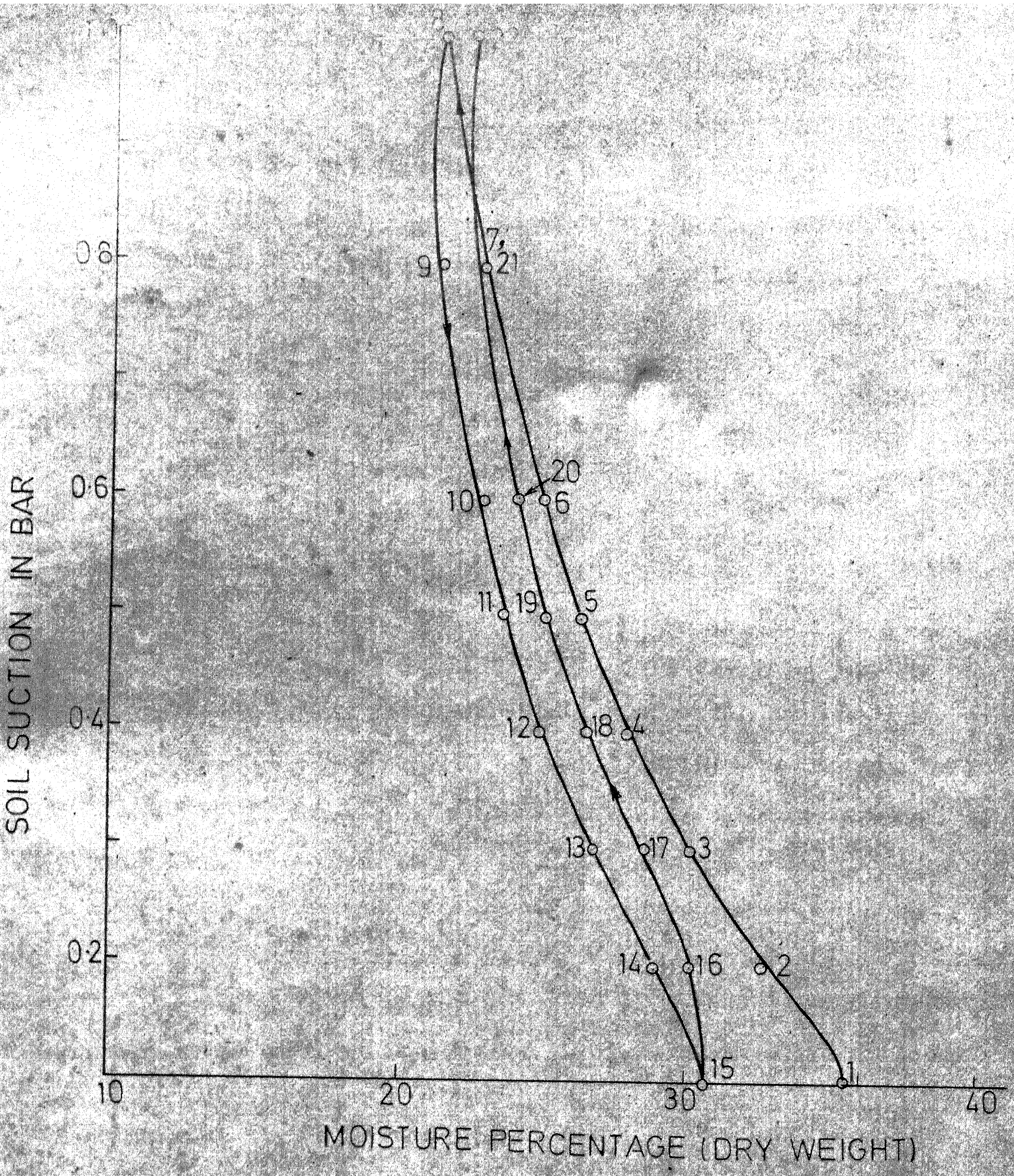


FIG. 10 HYSTERESIS EFFECT IN REGIONAL I.A.R.I. SOIL (VOLUMETRIC PRESSURE PLATE EXTRACTOR) SUCCESSIVE NUMBERS INDICATE EQUILIBRIUM VALUES AS MOISTURE WAS WITHDRAWN FROM SAMPLE, THEN ADDED, AND WITHDRAWN AGAIN

under gravity. It took 20 to 30 hours to approach equilibrium values. The same procedure was repeated thrice on the same sample. At the end of the run the soil sample was put in moisture box, kept in oven for 24 hours and moisture content on dry weight basis was determined. The moisture content at other suction values is determined by back calculation and is shown in Table 11. Hysteresis loop is shown in fig. 10.

4.1.3 Bulk Density:

In order to determine bulk density, a steel tube of 1.27 cm inner dia. and 6 cm height was used. It was hammered into the soil and then taken out by digging the sides. The whole sample was oven dried for 24 hours and bulk density was found out.

4.2 Field Experiments

4.2.1 Potential Evapotranspiration from Evapotranspirometer:

To find the potential evapotranspiration, an evapotranspirometer as discussed in Section 2.4 was used. Two pits of dimensions 152.5x152.5x67 cm and 61x61x90 cm were dug out in the field at a distance of 102 cm apart. The field tank of dimensions 5x5x2.5 ft was kept projecting 4 in. (10 cm) from the ground surface. In order to avoid irrigation water to get inside tank 'E' of dimensions 2x2x3 ft, the soil was raised on all the four sides and

it was closed from top with a cover. Tank 'A' was filled with the dug out soil and compacted to correspond approximately to the existing field density. Cowpeas was sown in the field as well as over the tank 'A'. Tensiometer as well as moisture blocks were embedded in the field near the tank. In the early stage of crop growth, tensiometer served as indicator for irrigation (for the reason given in Section 2.3.1) and during later stages moisture blocks were utilized for irrigation schedule. While irrigating field, tank 'A' was supplied with measured quantity of water sufficient to produce over flow. The amount of water supplied by tank 'D' (supply tank) and over flow in tank 'C' (over flow collection tank) were noted with the help of tape. The potential evapotranspiration for the period between two irrigations was found out by the following equation

$$E_{TP} = V_A + V_D + V_R - V_C - V_F \qquad (19)$$

where

E_{TP} = Potential evapotranspiration between two irrigation interval

V_A = Volume of water applied over field tank 'A'

V_D = Volume of water supplied by tank 'D'

V_R = Volume of rainfall measured by rain gauge

V_C = Volume of water collected in the over flow tank

V_F = Volume of run off collected in the run off tank

Using the above equation the evapotranspiration has been calculated for the two growing seasons and is listed in Table 6. Its sample calculation is given below:

SAMPLE CALCULATION FOR POTENTIAL EVAPOTRANSPIRATION BY EVAPOTRANSPIROMETER

Irrigation interval 23rd March to 2nd April

$V_A = 3.20$ cu.ft

Depth of water supplied by tank 'D' = 7.80 cm

$$V_D = 3.14 \times \frac{7.80}{30.4}$$

$= 0.810$ cu.ft

Rainfall (from rain recording gauge) = 7.40 mm

$$V_R = \frac{0.74 \times 25}{30.4}$$

$= 0.610$ cu.ft

Run off from tank 'F' = 10.30 cm

$$V_F = \frac{10.20}{30.4} \times 1.59$$

$= 0.542$

Over flow from tank 'C' = 15.40 cm

$$V_C = 0.6 \times \frac{15.40}{30.4}$$

$= 0.310$

$\therefore E_{TP}$ (from 23rd March to 2nd April) =

$= 3.20 + 0.810 + 0.610 - 0.542 - 0.310$

$= 3.768$ cu.ft

$$= \frac{3.768}{25} \times 304 = 45.93 \text{ mm}$$

(Note: The size of over flow collection tank was small so during heavy rain fall over flow was collected in tank 'E' and converted to the depth of tank 'C').

4.2.2 Measuring Daily Evaporation:

Daily evaporation was measured from two sources viz. Class-A pan and ordinary cans. Class-A pan as shown in fig. 6 was kept on raised soil plateform near the field over the wooden frame. The top was covered with 22 gage screen to avoid splashing and drinking by birds. Highest level was kept 4 cm below the top of pan to measure evaporation effeciently. Daily readings were taken at 9 A.M. with the help of sliding gage.

Ordinary cans of dimension 17.5 dia. and 19.5 cm height were embedded inside the soil to various depths. Fully embedded can was occasionally cleaned during days of dust storm.

4.2.3 Measuring Soil Moisture Level:

In order to determine soil moisture level and its availability to plants, three moisture blocks were buried to a depth of 2 ft. (61 cm). One block was buried at 6 in. (12.5 cm) from ground surface, second at 1.5 ft (37.5 cm) and third one at 2 ft (61 cm). Fourth block was buried inside tank 'A' at a depth of 50.8 cm to ensure the water

TABLE 12

Calibration of Soil Moisture Block at Field Condition with Tensiometer

Tensiometer Reading (20 cm depth) (Bar)	Soil Moisturemeter Reading of Moisture Block (20 cm depth)	Resistance from Conversion Table 13
0.13	92.5	138
0.18	90.2	178
0.28	86.0	260
0.36	82.0	340
0.45	77.8	445
0.58	72.0	600
0.65	68.8	700
0.75	63.2	900
0.84	58.0	1094

TABLE 13

Conversion Table Frost Soil Moisturemeter

Meter Reading	Ohms	Meter Reading	Ohms
0	Infinity	52	1,410
2	64,200	54	1,300
4	35,000	56	1,200
6	23,800	58	1,099
8	18,200	60	1,020
10	14,600	62	948
12	11,900	64	870
14	9,800	66	794
16	8,300	68	722
18	7,130	70	665
20	6,300	72	598
22	5,600	74	543
24	4,940	76	482
26	4,420	78	433
28	3,960	80	385
30	3,600	82	340
32	3,300	84	293
34	3,000	86	256
36	2,740	88	224
38	2,510	90	184
40	2,280	92	146
42	2,120	94	110
44	1,950	96	80
46	1,800	98	45
48	1,650	100	18
50	1,534		

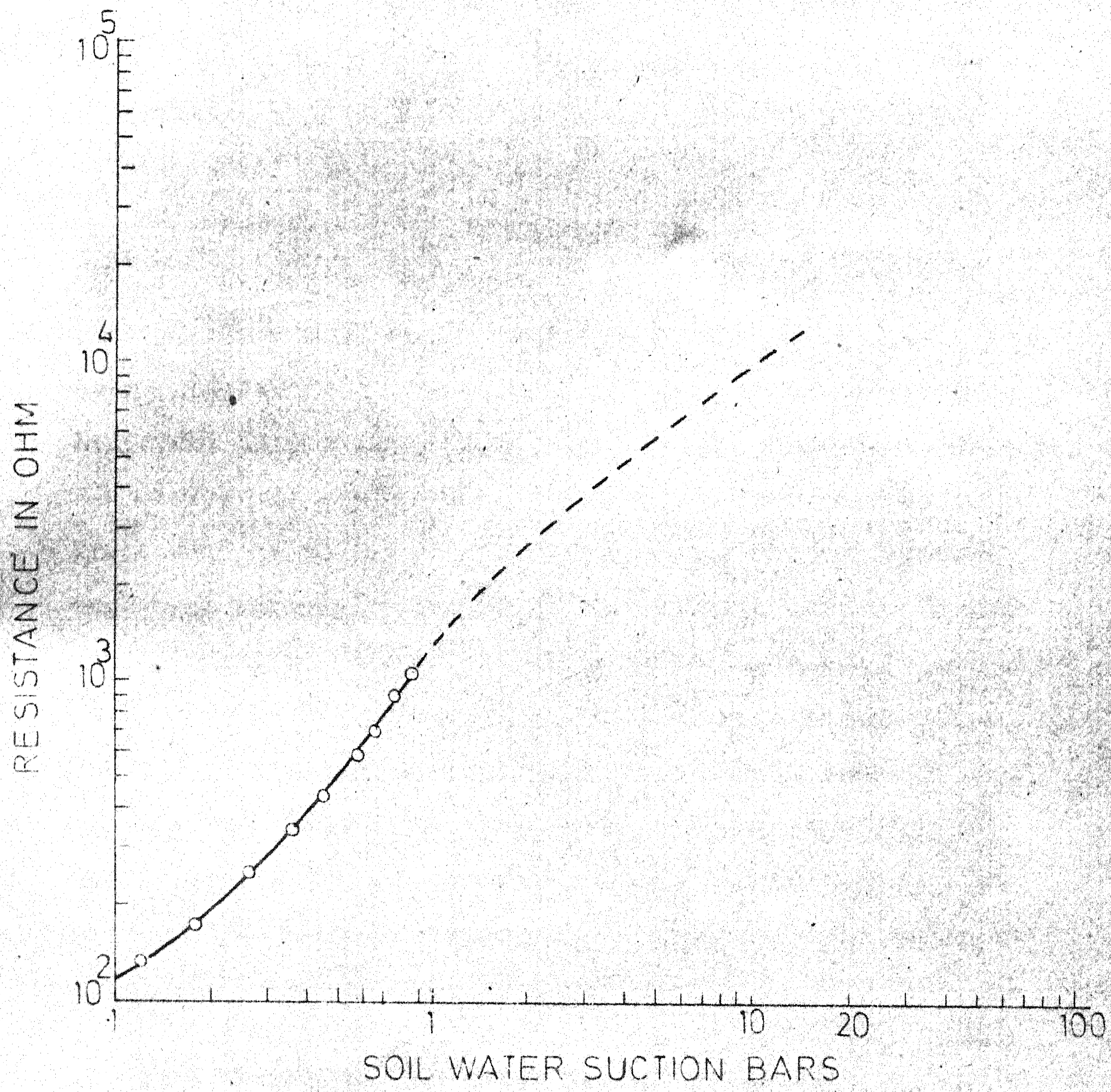


FIG.11 CALIBRATION CURVE FOR THE ELECTRICAL RESISTANCE UNIT

table position.

The moisture block was calibrated in field with tensiometer up to 0.85 bar tension. Table 12 shows the moisturemeter and corresponding tensiometer readings. Moisturementer readings were converted into resistance with the help of conversion Table 13. A graph (fig. 11) between resistance vs soil suction was drawn on log-log paper with scale equivalent to the curve supplied by Soil Moisture Equipment Corporation, California, U.S.A. The curve so drawn was similar to the curve supplied by manufacturers but at a displaced position. From 0.85 bar onward the calibration curve was extended parallel to the supplied curve. In this way a relation between moisturemeter readings and soil suction was established. Relation between soil suction and percentage of moisture content has already been shown in Section 3.1.1 and hence moisturemeter readings give indirect measure of soil moisture content and its availability to plants. In early stages of growth upper blocks readings were sufficient to decide irrigation schedule.

4.2.4 Measurement of Meterological Parameters:

Rainfall was measured with nonrecording gauge which was kept at the site. Wind speed was measured with cup type anemometer. It was kept near Class-A pan at a height of 4 ft above the ground surface. A thermohygrograph gave continuous record of temperature and relative humidity for 24 hours.

CHAPTER 5

ANALYSIS OF RESULTS AND DISCUSSION

5.1 Potential Evapotranspiration Variation with Crop Age

Cowpeas (Lobia) is grown both as pulse and fodder crop. It was grown from 28th July to 3rd December as pulse and from 13th February to 21st May as fodder crop. During first growing season, the atmospheric temperature decreased with increase in growing period while during second period, temperature increased with growing period.

In Table 6 potential evapotranspiration (consumptive use) for various periods of growth has been determined. A sample calculation is shown on page 47 and relationship between consumptive use and age of cowpeas is drawn for both growing periods as shown in fig. 12. At the beginning of plant growth (from 28th July to 2nd August) average daily E_{TP} is 1.14 mm and goes on increasing till the end of September and reaches 3.89 mm (from 7th September to 21st September). After attaining the highest value it decreases to 1.85 mm (from 13th November to 3rd December).

The fig. 12 also shows E_{TP} from 13th February to 21st May. Since it was grown as a fodder crop during the period, the main concern was to increase foliage. The irrigation frequency was increased during this period. In this case average daily E_{TP} is 1.3 mm (18th February to 2nd March). The maximum value of 10.16 mm is attained

around first week of May and afterwards it decreases. The average maximum E_{TP} during the summer growing season is two and half times that of winter growing season. Thus environmental temperature is a single major factor which affects the peak consumptive use.

Peak consumptive use of crops grown in an area is an important factor in designing the irrigation structures. Evapotranspiration consists of loss from soil surface and transpiration from the plants. During the early stages of plant growth losses are chiefly due to evaporation from the bare soil. As the plants grow, considerable water is lost through openings in the plant leaves called stomata. As the plant grows its root system also grows in areal extent and depth, enabling the plant to draw water from a much bigger soil volume and to maintain transpiration at a potential rate even though the soil moisture goes on decreasing in the upper layer of soil. When the tension in the soil-water increases beyond one atmosphere, transpiration rate starts decreasing and is controlled by stomatal openings (9). After the crop matures, leaves start falling down and transpiration occurs through the remaining leaves and stem, so transpiration rate further falls down.

5.2 Relationship of Evaporation from Simple Can and Class-A Pan

Figs. 13 and 14 show plots of cumulative

evaporation from Class-A pan vs cumulative evaporation from ordinary cans (refer also to Section 2.5) buried in the soil to various percentages of their height. Evaporation from fully buried can is very close to the evaporation from Class-A pan and goes on deviating as the burial depth of can decreases. Evaporation goes on increasing with decrease in the burial depth of can. It is due to extra radiation falling over the projected surface of can and thus contributing additional energy for evaporation.

5.3 Relationship Between Cumulative E_{TP} and Evaporation

The relationship between cumulative potential evapotranspiration and cumulative evaporation from Class-A pan and ordinary can is obtained for both the growing seasons and shown in figs. 15 and 16. For winter and summer growing periods there is a good correlation between the E_{TP} and evaporation from Class-A pan. Thus evaporation from a standard pan is an index for the estimation of E_{TP}. As mentioned in Section 5.2, the evaporation from fully buried cans corresponds closely to that of Class-A pan. Hence rather than going in for costly copper pan, one can install 'cans' of dimension 17.5 cm dia. and 19.5 cm high and obtain evaporation data close to that of Class-A pan.

5.4 Relationship Between Daily E_{TP} and Evaporation

Fig. 17 shows a plot of average daily E_{TP} vs

average evaporation from Class-A pan for both growing periods. From August to September, evaporation increases and correspondingly E_{TP} increases but beyond that both evaporation and E_{TP} decreases. During summer season both evaporation and E_{TP} increases. Thus E_{TP} increases with increase in growing period up to certain percentage and then starts decreasing.

5.5 Variation of Crop Factor with Growth Percentage

Fig. 18 shows the relationship between crop factor (ratio of average E_{TP} to evaporation) and percentage of growing periods. For winter growing season, crop factor (C_f) increases with increase in growth and attains the maximum value (0.85) around 65% of growth period and then starts decreasing.

For summer growing season, C_f reaches the maximum value (1.0) around 55% of growth and then decreases till 65% of growth period. It again increases for short duration and then starts decreasing. The kink in the curve after the maximum value is reached, may be due to the effect of hot winds which cause temporary wilting of plant leaves. So, even though a lot of moisture is still available in the root zone, plant transpires at a very low rate causing low E_{TP} rate (9). When the environment becomes a little cooler, the plant leaves regain their turgidity and start transpiring at a higher rate, contributing to higher C_f and after that it starts decreasing.

5.6 Comparison of Evaporation by Christiansen Method

The relationship between average daily evaporation measured from Class-A pan and computed by using Christiansen's method is shown in fig. 19. The correlation is good between the measured and computed values during winter and summer growing periods except in the months of April and May. Usually, a dust film use to form over the water surface in the Class-A pan due to heavy dust storms during these months. This film causes reduction in the evaporation rate. This explains why the computed values are more than measured ones. In the region like Kanpur where evaporation losses are appreciable, Christiansen's method gives quite reliable evaporation data.

5.7 Comparison of E_{TP} by Penman and Thornthwaite Methds

Fig. 20 shows plots of measured E_{TP} from evapotranspirometer and computed E_{TP} by Penman and Thornthwaite method by using Table 3 and 7. From the figure it is seen that monthly E_{TP} computed by Thornthwaite does not agree with measured value. This method does not take into account other factors affecting E_{TP} except average temperature. This may be the reason for computed values being lower than the measured ones. Penman method gives good correlation during winter growing season but not in summer months. This is due to the fact that the coefficients used in Penman equation were determined for a humid area not far from the

ocean and not for arid areas. So during months of high humidity and low temperature i.e. August to December, there is a good correlation between the measured and computed values. In the month of April, crop from the surrounding field had been harvested and this condition resulted in a greater quantity of energy being available for consumptive use than would be indicated by incoming solar energy. So measured values of E_{TP} are greater than the computed values.

5.8 Comparison of E_{TP} by Lowry-Johnson Method

Page 36 gives the total computed value of consumptive use for the two growing seasons by Lowry-Johnson method. Computed value (90 cm) is quite close to the actual value of consumptive use (94.14 cm) for two growing periods.

5.9 Relationship Between Blaney-Criddle Coefficient, Crop Factor

Fig. 21 gives a relationship between Blaney-Criddle coefficient, crop factor and age of cowpeas (using Table 7 and 8). There is a good correlation between crop factor determined from field study and Blaney-Criddle coefficient computed by using temperature and percentage of daytime hours. They do not take into account the effect of windspeed, relative humidity etc. and that is why some scatter is there in the plot.

5.10 Irrigation Schedule by Ordinary Can

Table 14 and fig. 22 gives irrigation schedule during summer growing period and depth of water to be evaporated from ordinary can before applying next irrigation. It is developed by using moisture retention curve, crop coefficient, root zone depth and evaporation from ordinary can. The Standard Weather Bureau Pan (Class-A pan) shown in fig. 6 which is generally used in research is too cumbersome to be practical for most irrigators. A simple type of evaporation pan which provides fairly close correlation is needed for farm use. As seen in Section 5.2 evaporation from fully buried can is very close to that from Class-A pan. Fully buried can is filled with water to 18 cm depth and evaporation is recorded daily. When the water level in the can drops by an amount equal to the amount of water to be applied, it is time to irrigate. The irrigation schedule so developed is very close to the actual schedule followed (by using moisture block) during summer growing season except in the latter part. This is due to the reason that actual root depth is more than what is used to calculate available water.

Small rains add water to the pan as well as to the soil, keeping both in balance. But during intense rainfall this method can not be followed by the farmer unless he makes a good estimate of the soil moisture level.

TABLE 14

Table Showing Irrigation Schedule with Ordinary Can

Average Root Depth 'd' (cm)	Total Depth of Water in the Root Zone in cm $D=\frac{d_b P_w d}{100}$	Percentage Allowed to Deplete Before Irrigation	Depth to be Depleted (mm)	Crop Factor 'C_f'	Depth of Water to be Evaporated from Ordinary Can, mm	Irrigation Date	Actual Date of Irrigation (Soil Moisture Block)
5.0	0.945	40	3.8	0.160	24.0	Feb 19	Feb 18
15.0	2.840	40	11.3	0.390	30.0	Mar 1	Mar 3
25.0	4.720	50	23.6	0.470	50.0	Mar 10	Mar 12
35.0	6.610	50	33.1	0.520	64.0	Mar 21	Mar 23
45.0	8.500	60	51.0	0.645	80.0	Apr 2	Apr 3
55.0	10.400	60	62.5	0.830	75.0	Apr 9	Apr 11
65.0	12.300	60	74.5	1.000	74.5	Apr 17	Apr 21
65.0	12.300	70	87.0	0.860	101.0	Apr 28	May 2
65.0	12.300	70	87.0	0.960	91.0	May 6	May 12
65.0	12.300	70	87.0	0.860	101.0	May 15	-

From soil moisture retention curve field capacity (F.C.) = 26.60

Permanent wilting point (P.W.P.) = 12.50

$\therefore\ P_w = 14.1$

$$\text{Bulk density} = \frac{\text{Dry weight of the soil}}{\text{Volume of wet soil}} = 1.34$$

If there is heavy rainfall, the soil will be brought to field capacity. Now if the farmer applies irrigation when the water level in the can drops to the predetermined depth, then it will lead to earlier irrigation. He is not taking into consideration the additional root depth which will give more available water for plants.

5.11 Hysteresis Effect in the Soil

Fig. 10 shows the hysteresis loop developed by volumetric pressure plate extractor. From the figure it seems that no single curve can be taken as characteristic for a given soil sample. A well established hysteresis means, measured values of water retention at given suction are different depending upon wheather the soil is an wetting or drying cycle. Theoretical studies on soil water transfer usually resolves the problem of hysteresis by working either on a single drying or wetting curve. In field studies this is not possible and attempts to correlate tensiometer or soil moisturemeter readings with water content have not always proven satisfactory.

Hysteresis is not the only factor that may cause variation between measured water content and tension. In the field calibration of instruments, where soil samples are taken for relating water content to instrument readings, local variability in soil texture and structure will also cause variation in the calibration curve.

CHAPTER 6

CONCLUSION AND SUGGESTION FOR FURTHER RESEARCH

6.1 Conclusion

Based on the experimental results and analysis, the following conclusions are drawn:

i. Peak consumptive use of cowpeas appears to be two and half times more during summer growing season than in winter season.

ii. Evaporation from fully buried cans is very close to the evaporation from Class-A pan and goes on increasing as burial depth decreases.

iii. Crop factor (ratio of potential evapotranspiration to evaporation) increases till certain percentage of growth and then decreases.

iv. Christiansen's method for estimating evaporation is best suited for this region.

v. Penman method, though provides fairly close correlation between the estimated and measured values of E_{TP} during winter growing season, is too cumbersome to be practical. Thornthwaite method is not applicable for this region.

vi. Lowry-Johnson method does not tell anything about monthly consumptive use values but gives good estimate of seasonal value.

vii. Blaney-Criddle coefficients can be used to find out the consumptive use of cowpeas in any other region provided temperature and day time hours data are available.

viii. Evaporation from fully buried cans give good estimate for the irrigation schedule during summer, provided they are well located and evaporation data are correlated with the consumptive use of crop to be irrigated.

6.2 Suggestion for Further Research

Number of soil moisture blocks was too less to get a good sample of the area to be irrigated. There should be sufficient number of moisture blocks, so that one can have overall picture of moisture level throughout the field and not at a single point. To calibrate the moisture blocks in the laboratory, pressure plate apparatus (0-5 bar) is required.

Ten Bourden gauges are required to make use of the existing tensiometers. Whenever the tension increases beyond 0.85 bar, air use to enter the porous cup and thus give wrong readings. A vacuum service unit is needed for removal of air.

Recently 'Quick Draw' Tensiometer has been developed by Soil Moisture Equipment Corporation, California, U.S.A., which do not require any adjustment. The instrument

consists of the measuring probe, coring tool and carrying sheath. With a single tensiometer one can have the idea of moisture level throughout the field.

The design of evapotranspirometer used in the study allows 2 ft root depth but actually root depth varies from 3 to 3.5 ft. So, for further studies on some other crops the design of evapotranspirometer should be such that plants grow alike in the tank as well as in field.

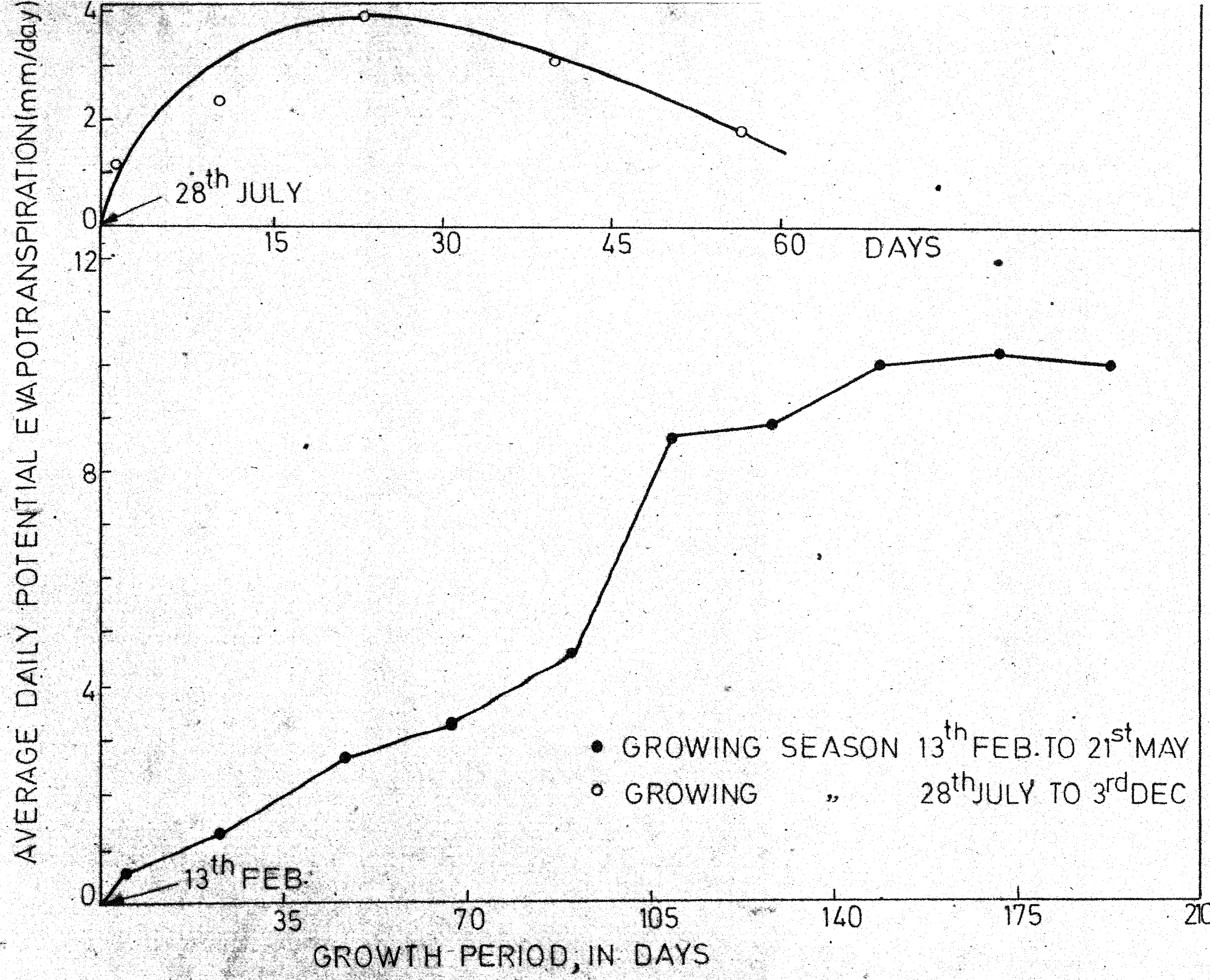


FIG.12 RELATION BETWEEN AVERAGE DAILY POTENTIAL EVAPOTRANSPIRATION BETWEEN TWO IRRIGATION INTERVAL AND GROWTH PERIOD IN DAYS

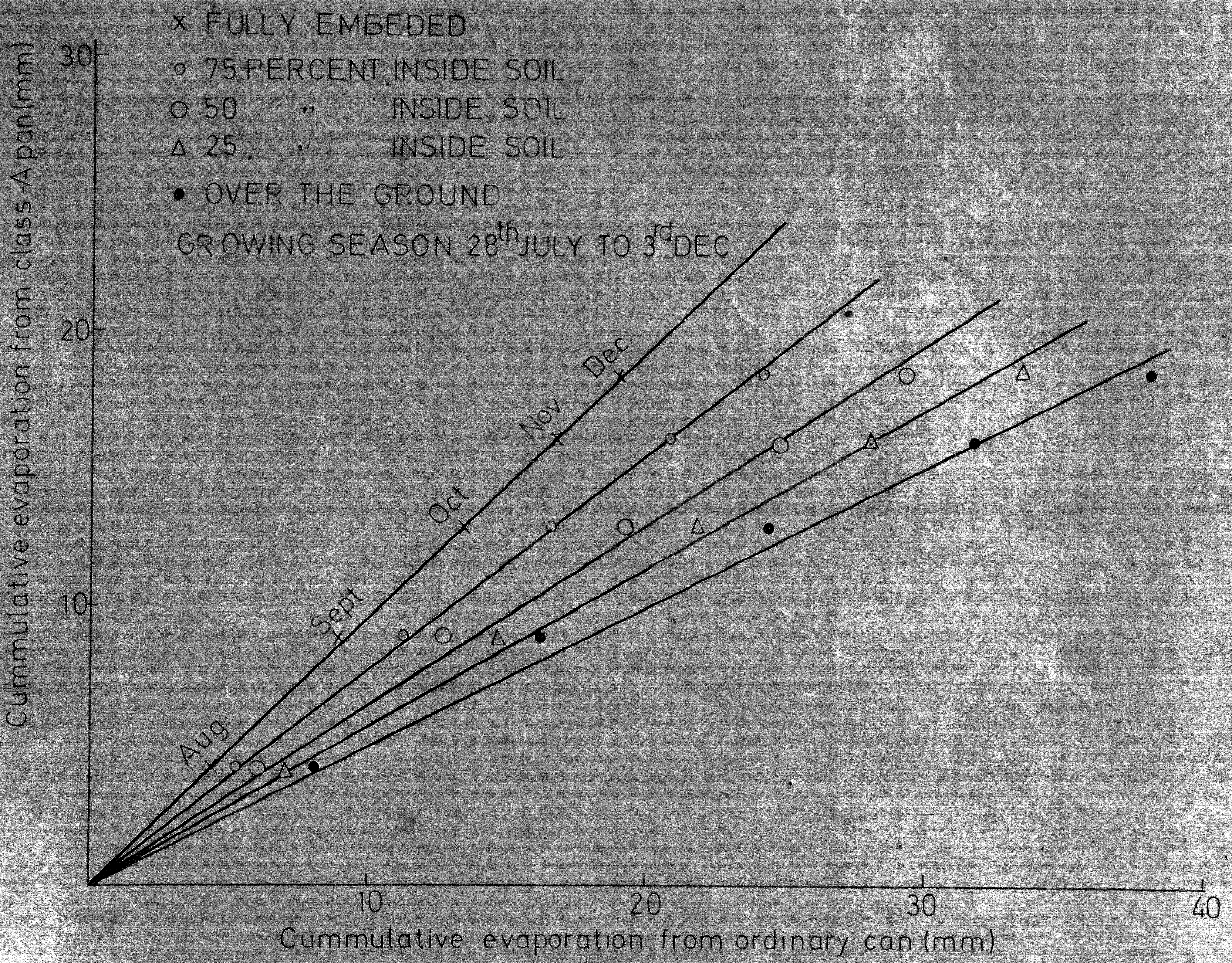


FIG.13 RELATION OF AVERAGE DAILY EVAPORATION FROM CLASS-A PAN TO EVAPORATION FROM ORDINARY CANS EMBEDED TO VARIOUS DEPTHS

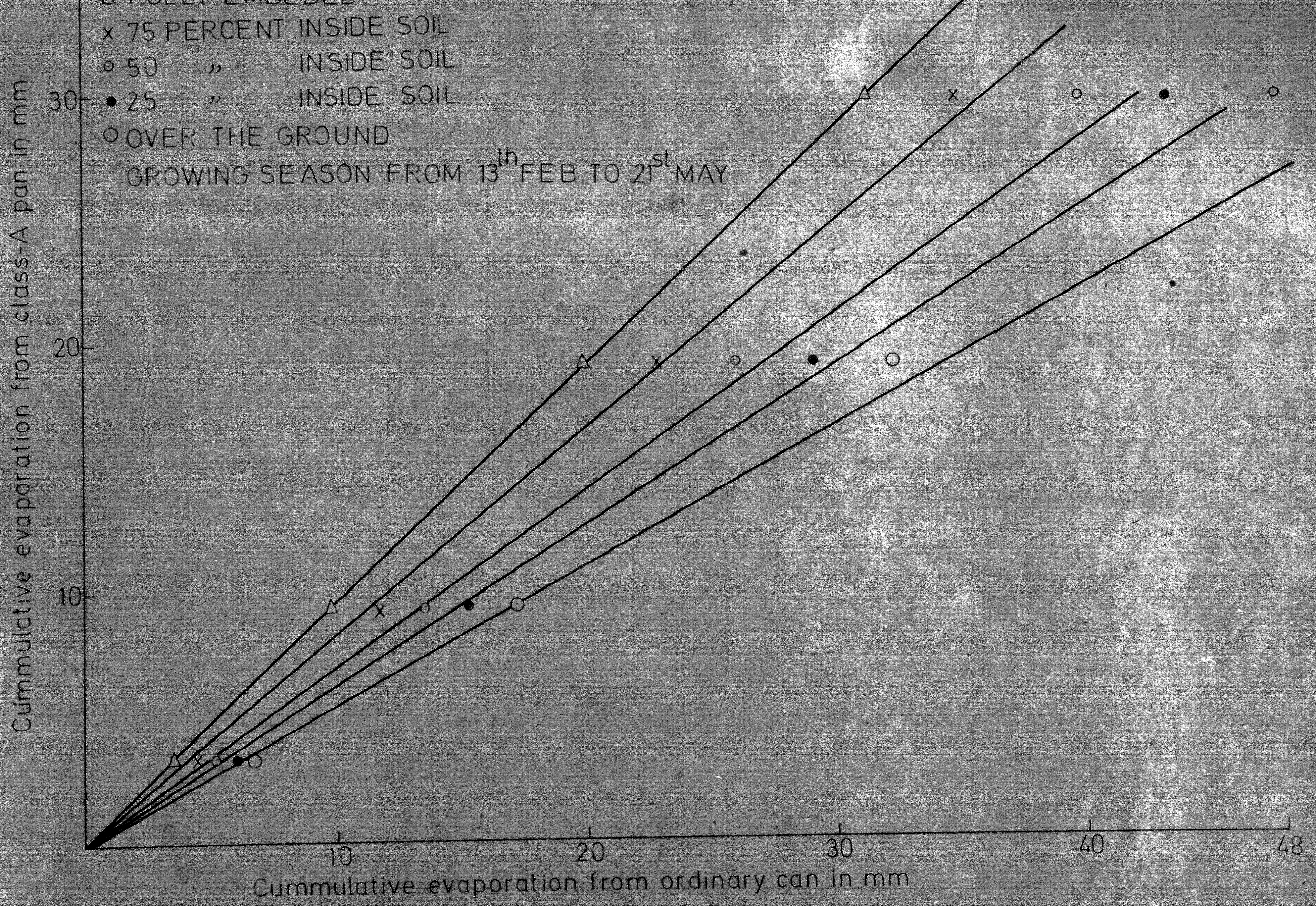


FIG.14 RELATION OF AVERAGE DAILY EVAPORATION FROM CLASS A PAN TO EVAPORATION FROM ORDINARY CANS EMBEDED TO VARIOUS DEPTHS

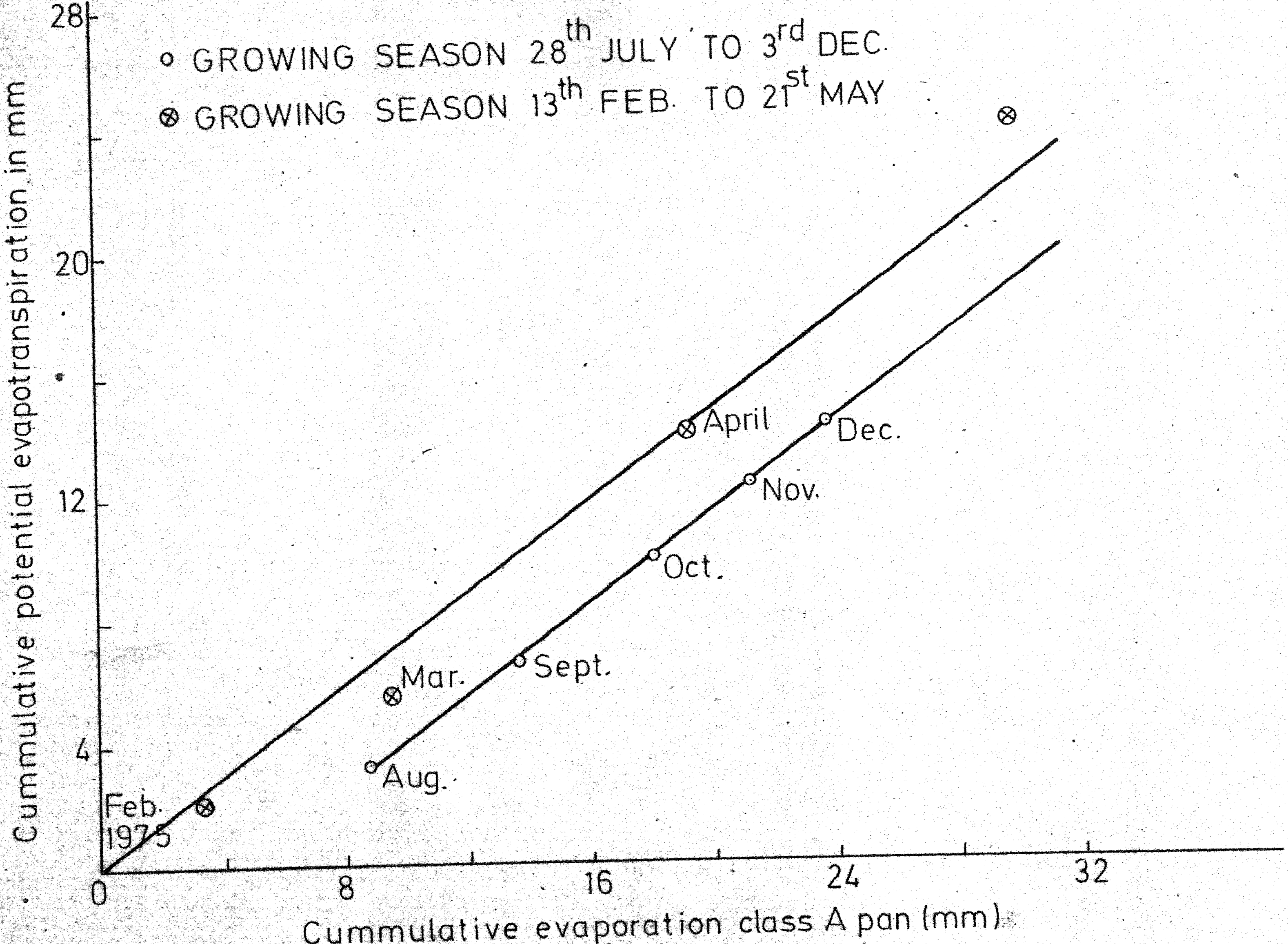


FIG.15 RELATION OF CUMMULATIVE POTENTIAL EVAPOTRANSPIRATION FOR COW-PEAS TO EVAPORATION FROM CLASS-A PAN

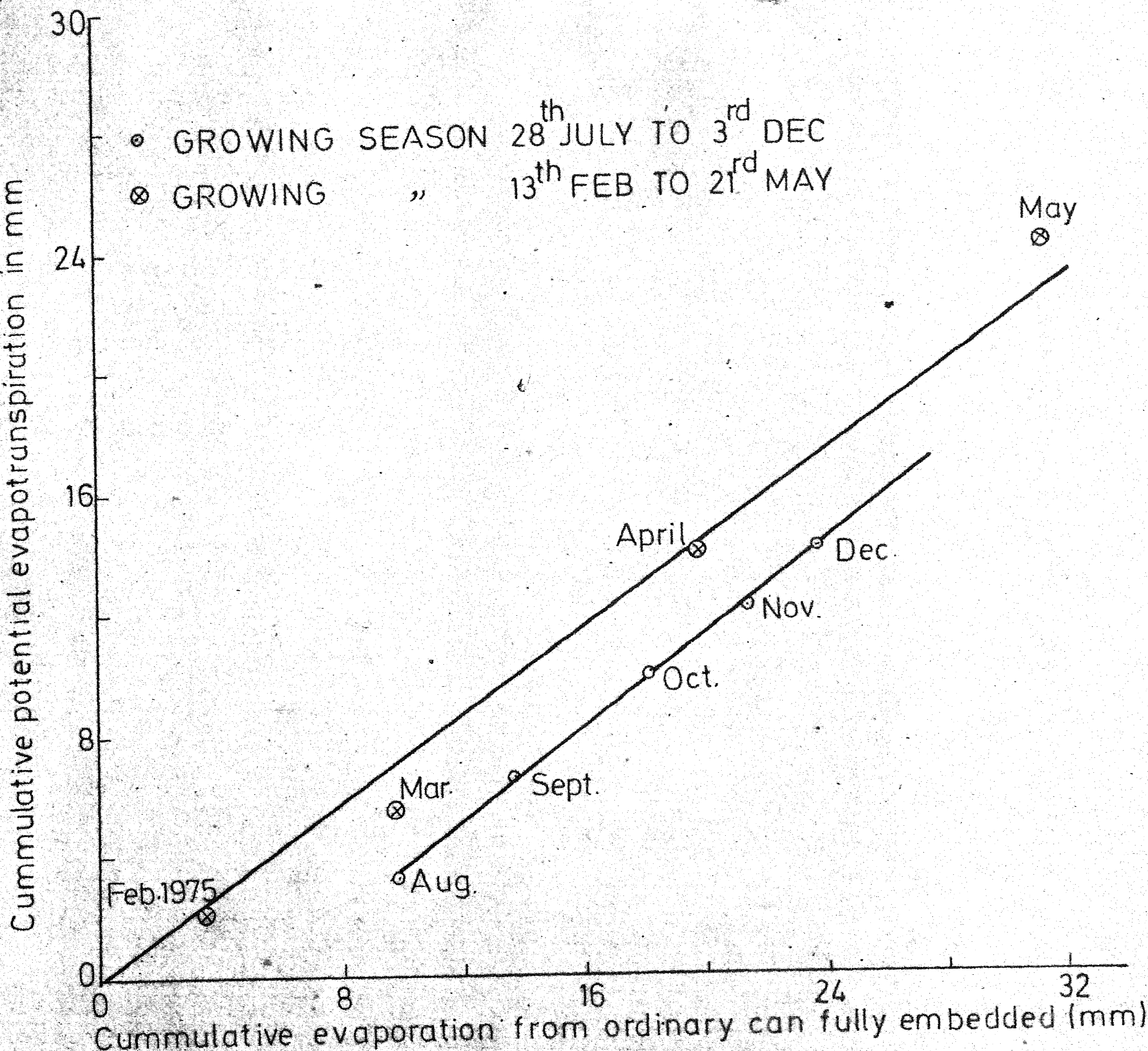


FIG.16 RELATION OF AVERAGE CUMMULATIVE POTENTIAL EVAPOTRANSPIRATION FOR COW-PEAS TO EVAPORATION FROM ORDINARY CAN

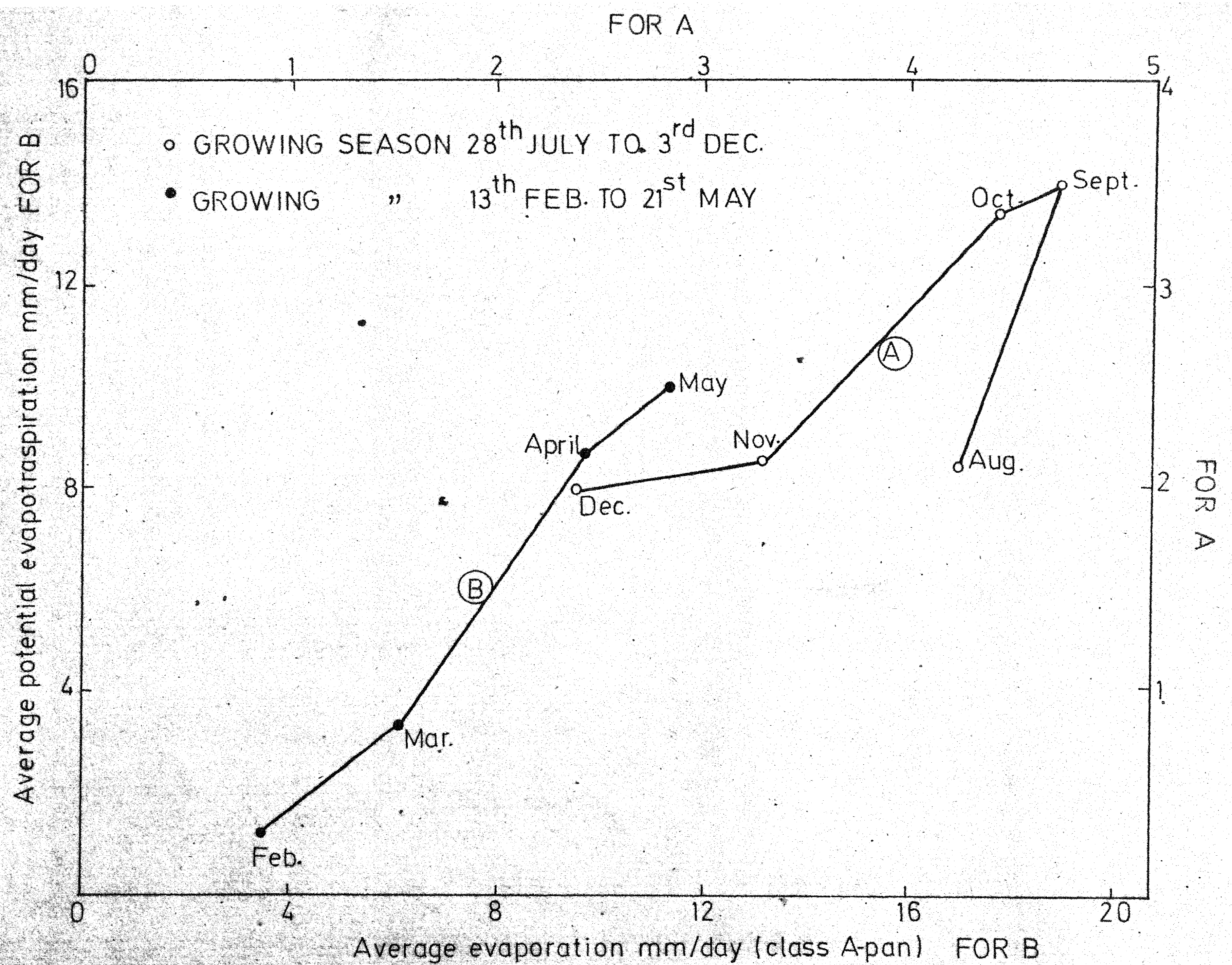


FIG.17 RELATION OF AVERAGE DAILY EVAPOTRANSPIRATION TO EVAPERATION FROM CLASS A PAN

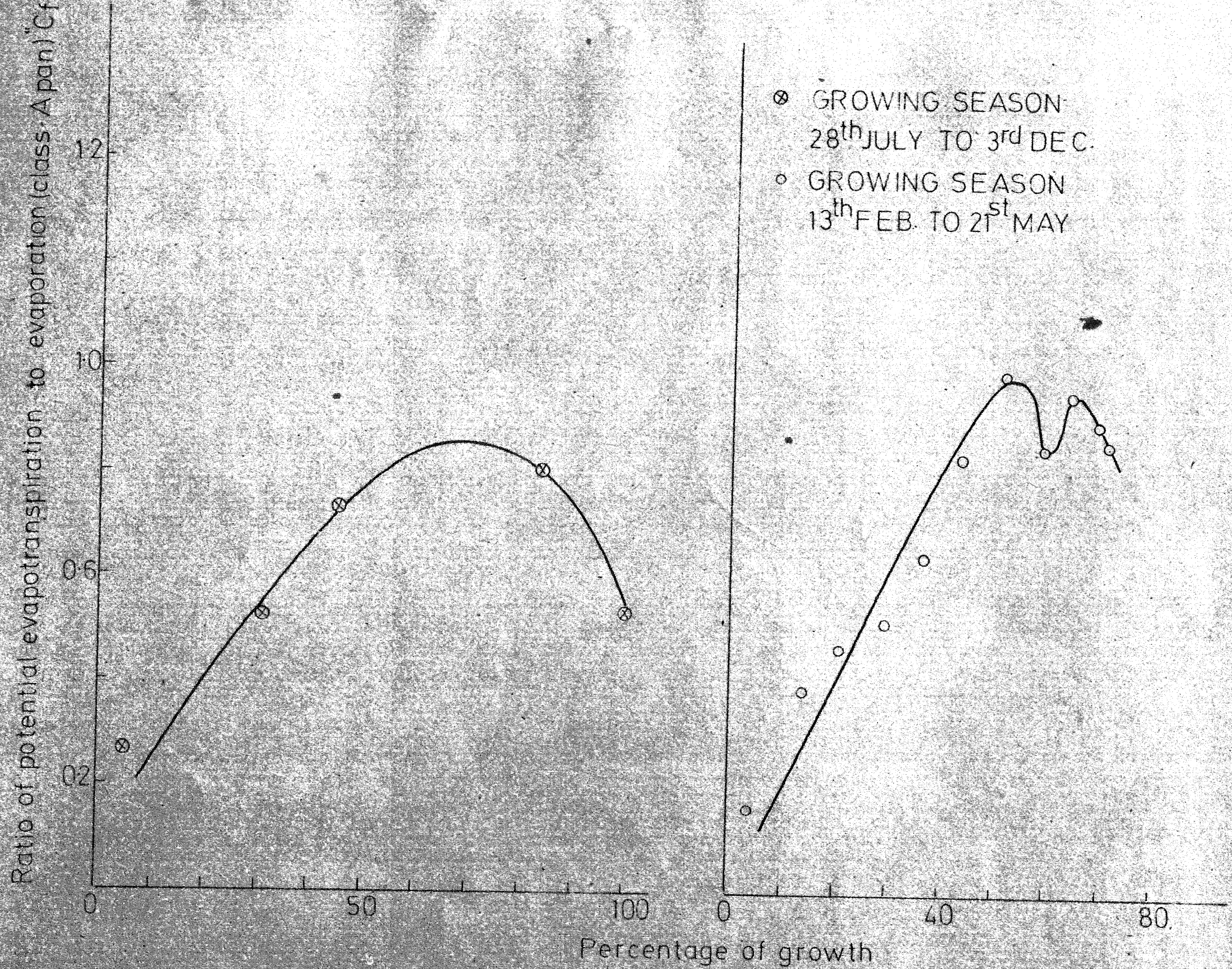


FIG.18 RELATIONSHIP BETWEEN POTENTIAL EVAPOTRANSPIRATION-EVAPORATION RATIO (CROP FACTOR) TO RELATIVE GROWTH OF COWPEAS

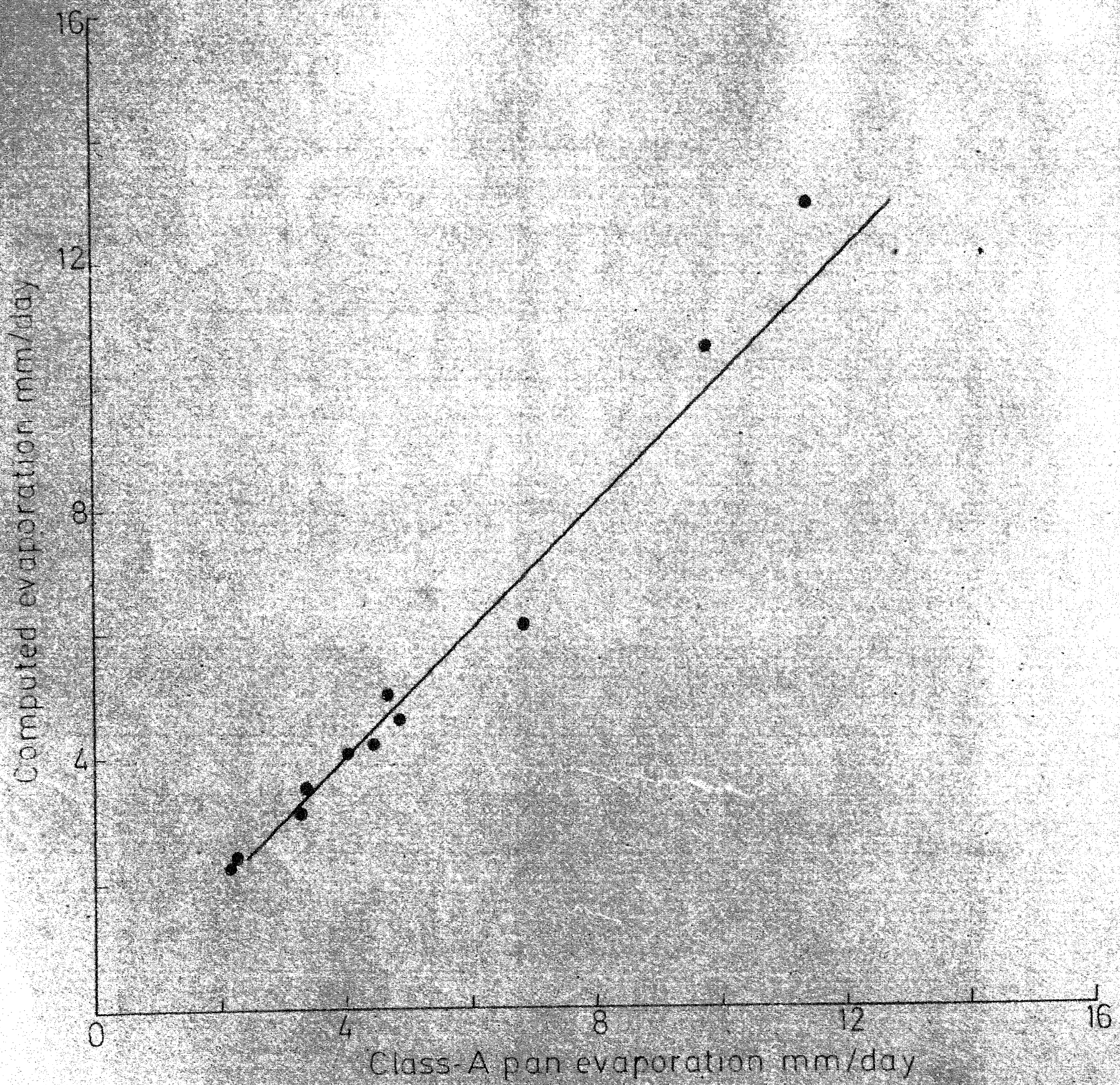


FIG 19 COMPARISON BETWEEN CLASS-A PAN EVAPORATION AND EVAPORATION COMPUTED BY CHRISTIANSEN METHOD

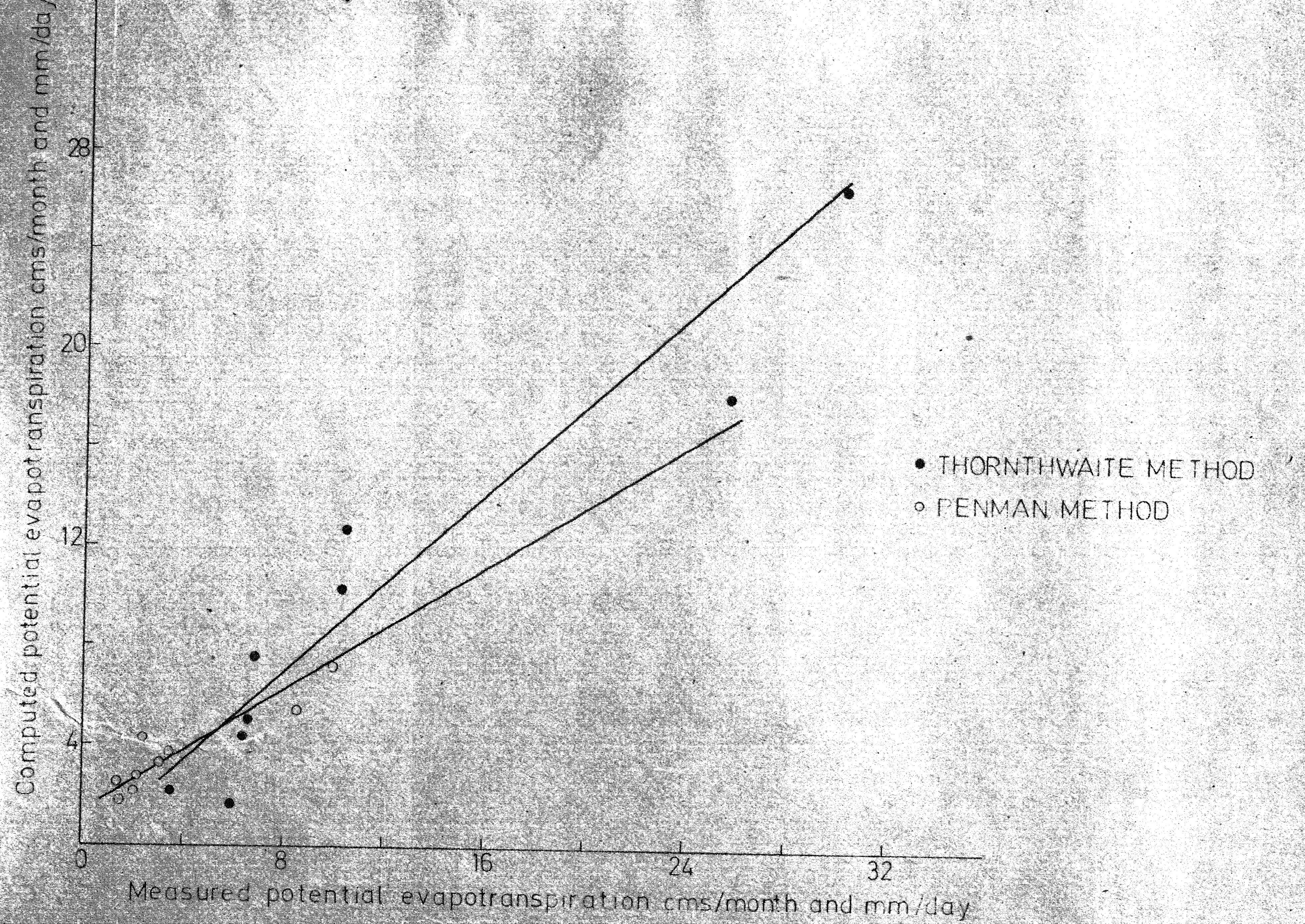


FIG 20 COMPARISON BETWEEN MEASURED AND COMPUTED POTENTIAL EVAPOTRANSPIRATION BY THORNTHWAITE AND PENMAN METHOD

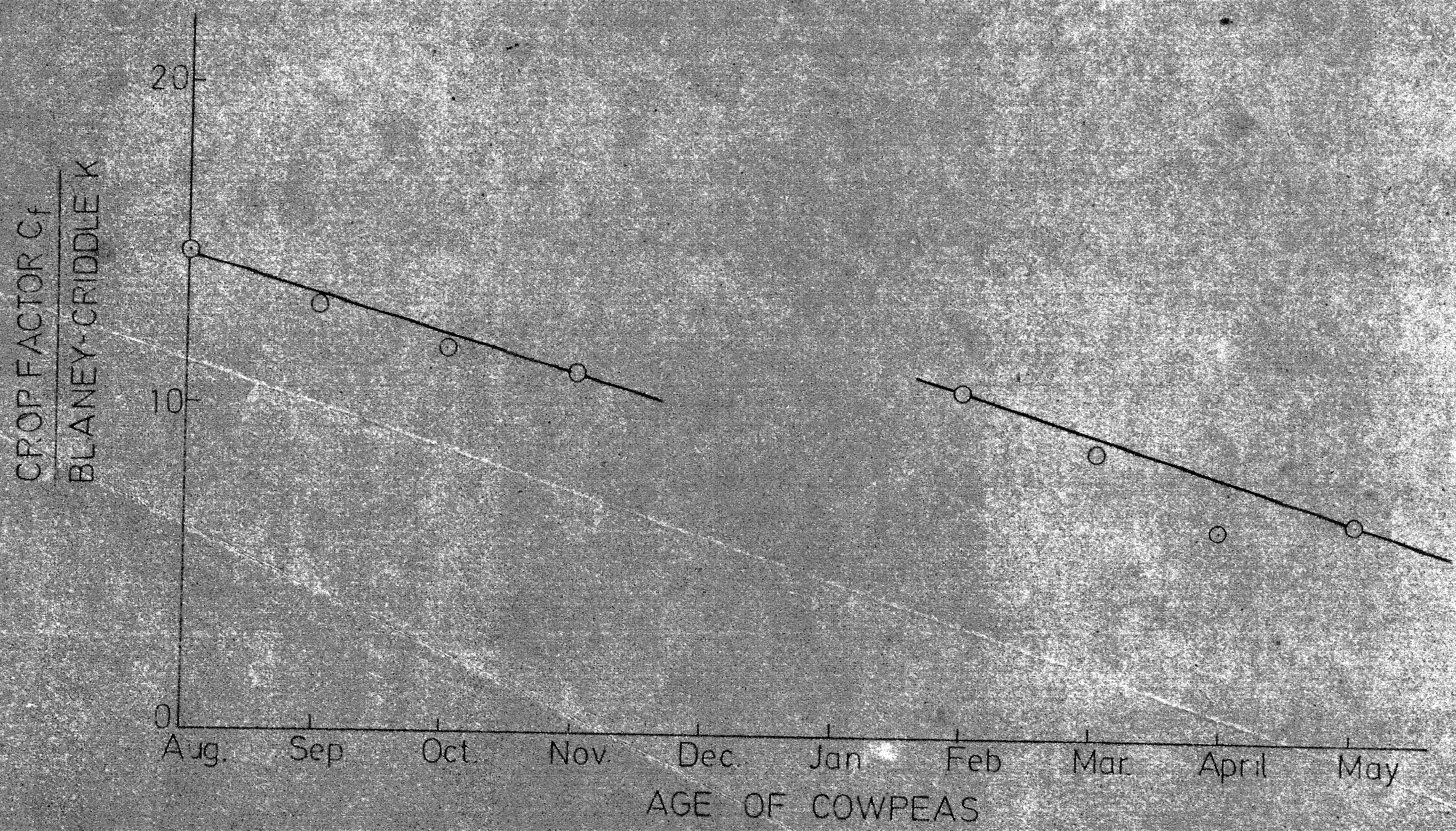


FIG. 21 RELATIONSHIP BETWEEN CROP FACTOR (C_f), BLANEY-CRIDDLE COEFFICIENT (K) AND AGE OF COWPEAS

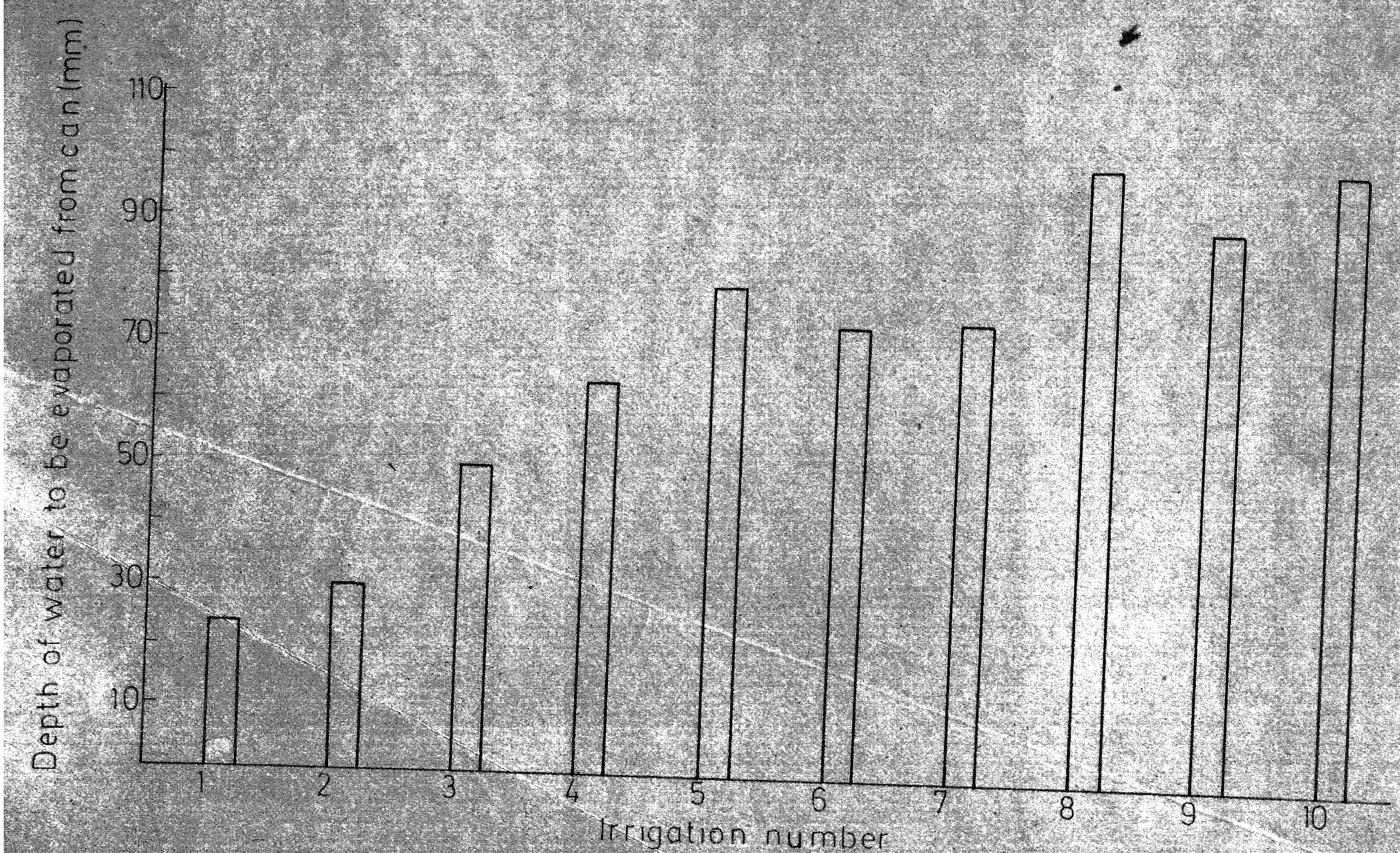


FIG 22 SHOWING DEPTH OF WATER TO BE EVAPORATED FROM FULLY BURIED CAN BEFORE APPLYING NEXT IRRIGATION

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The raw data collected and used in the thesis are all assembled and given in appendix which follows.

APPENDIX

TABLE A1: Table Showing Meterological Data for the Month of July 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	38.5	30.5	70	47	58.5	5.61	8.0
2	9.2	41.5	27.5	84	74	79.0	8.06	7.2
3	-	32.6	25.8	83	74	78.5	9.94	6.0
4	-	36.3	26.6	76	68	72.0	2.01	3.4
5	0.5	35.7	27.9	77	53	65.0	3.57	5.5
6	-	40.2	27.8	67	46	56.5	6.61	10.0
7	0.5	40.8	30.9	62	48	55.0	7.59	10.5
8	-	42.5	31.0	84	49	66.5	7.49	12.0
9	-	37.5	30.0	77	80	78.5	7.61	7.0
10	-	38.4	25.8	79	91	85.5	4.94	6.8
11	10.0	35.6	26.2	84	65	74.5	3.68	3.0
12	4.0	36.1	28.1	91	80	85.5	5.19	2.5
13	3.1	31.8	28.2	91	84	87.5	4.24	4.1
14	-	32.3	27.7	91	84	87.5	3.16	2.0
15	0.8	28.8	27.1	91	91	91.0	4.89	2.8
16	16.1	30.1	26.3	96	80	88.0	7.13	4.1
17	6.6	29.2	25.2	91	100	95.5	8.12	2.6
18	26.8	28.1	25.3	95	87	91.0	8.68	2.8
19	1.9	26.6	25.1	91	96	93.5	10.24	2.9
20	11.0	28.2	24.8	95	87	91.0	9.59	2.0
21	4.2	28.3	24.6	91	84	87.5	10.01	3.2
22	0.2	30.5	25.9	91	80	85.5	7.34	3.5
23	3.4	29.2	24.9	91	80	85.5	4.79	2.4
24	5.0	32.1	26.3	96	87	91.5	4.40	3.0
25	3.6	28.7	26.2	96	80	88.0	8.17	2.6
26	3.7	30.2	25.5	96	80	88.0	10.55	2.7
27	11.5	31.1	24.3	85	73	84.0	9.42	2.5
28	-	31.2	26.1	87	74	80.5	7.57	3.0
29	-	33.5	27.6	87	87	87.0	7.62	5.0
30	1.2	33.2	25.7	87	77	82.0	3.06	3.2
31	-	32.3	28.1	87	80	83.5	5.33	4.8

TABLE A2: Table Showing Meterological Data for the Month of August 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	32.1	27.8	84	65	74.5	6.8	4.4
2	-	33.2	26.7	91	77	84.0	6.0	4.5
3	-	32.2	26.9	87	88	87.5	4.2	3.8
4	1.1	32.5	27.6	87	74	80.5	3.8	4.1
5	12.0	34.2	26.1	91	96	93.5	4.5	3.6
6	6.4	28.8	25.1	96	87	91.5	3.1	2.4
7	3.0	28.6	25.5	91	91	91.0	2.0	2.9
8	7.4	27.7	26.2	96	96	96.0	2.4	2.4
9	3.6	29.9	28.3	91	86	87.5	3.5	3.6
10	3.6	32.1	28.0	91	84	87.5	3.1	3.6
11	-	33.2	27.6	92	88	90.0	3.9	3.3
12	0.5	34.1	27.8	96	83	89.5	3.4	4.5
13	-	30.2	26.5	92	74	83.0	2.0	3.7
14	-	33.3	26.2	91	87	89.0	3.4	4.2
15	0.4	34.0	25.9	96	100	98.0	2.0	3.9
16	1.5	31.7	26.5	91	77	84.0	5.0	4.5
17	-	32.9	26.8	84	74	79.0	4.4	4.8
18	9.5	30.9	26.2	84	74	79.0	8.9	4.5
19	6.0	30.1	26.3	83	80	81.5	8.4	4.8
20	15.9	30.8	26.0	83	84	83.5	5.5	2.9
21	3.5	30.7	25.0	87	87	87.0	6.3	8.5
22	1.2	27.9	23.8	95	76	85.5	4.3	4.2
23	0.3	30.4	25.9	96	100	98.0	2.9	4.3
24	0.3	29.1	24.8	91	77	84.0	2.2	3.8
25	4.0	33.3	25.6	87	74	80.5	4.3	2.4
26	-	33.1	26.1	87	74	80.5	4.3	4.0
27	-	32.9	27.0	91	96	93.5	4.9	6.0
28	1.5	29.6	25.8	79	68	73.5	5.3	3.5
29	-	35.0	24.9	83	68	75.5	9.5	6.0
30	-	35.7	26.2	75	59	67.0	12.4	4.0
31	-	36.0	25.1	75	78	76.5	17.4	7.0

TABLE A3: Table Showing Meterological Data for the Month of September 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	36.1	25.0	75	68	71.5	6.40	7.0
2	-	36.2	25.2	78	65	71.5	6.68	7.0
3	-	35.8	24.1	79	59	69.0	6.63	7.0
4	-	35.7	26.2	83	78	80.5	6.97	7.0
5	-	36.3	26.4	79	63	71.0	7.19	6.0
6	-	37.2	24.5	79	63	71.0	6.26	6.0
7	-	36.7	25.9	79	57	68.0	6.84	9.0
8	-	37.0	26.8	76	66	71.0	4.41	8.0
9	-	38.1	26.7	80	85	82.5	4.59	6.0
10	7.7	35.2	23.0	91	96	93.5	6.15	1.7
11	0.9	31.3	24.4	91	84	87.5	5.47	6.9
12	-	32.2	23.3	91	77	84.0	5.16	5.0
13	-	33.1	26.5	88	72	80.0	0.75	6.0
14	-	37.1	24.4	87	65	76.0	3.78	6.0
15	-	36.7	24.9	86	75	85.5	1.25	4.0
16	-	35.9	24.8	87	81	84.0	1.67	5.0
17	-	33.8	26.0	91	66	78.5	4.45	4.0
18	-	32.7	24.8	91	80	85.5	6.48	6.0
19	-	30.9	24.0	91	84	87.5	5.61	4.0
20	-	32.1	24.2	95	81	88.0	3.65	4.0
21	-	33.3	23.9	95	81	88.0	3.67	4.0
22	-	32.2	23.3	91	74	82.5	5.25	4.0
23	-	32.4	22.2	95	77	86.0	7.54	2.0
24	27.0	30.2	25.3	96	95	95.5	1.80	1.7
25	-	28.7	24.1	95	92	93.5	3.06	1.0
26	-	31.8	24.2	87	78	82.5	3.98	3.0
27	-	34.8	24.5	83	88	85.5	1.70	3.0
28	-	34.0	23.0	95	84	89.5	4.03	3.5
29	2.5	30.0	22.6	95	81	88.0	2.75	2.0
30	1.9	29.6	22.8	96	81	88.5	3.72	1.9

TABLE A4: Table Showing Meterological Data for the Month of October 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	32.2	23.9	83	68	75.5	3.25	5.0
2	-	35.3	22.1	75	65	70.0	3.75	6.0
3	-	36.2	24.3	69	61	65.0	3.12	6.0
4	-	33.0	17.3	72	60	66.0	3.99	6.0
5	-	33.3	17.5	77	74	75.5	3.94	6.0
6	-	34.4	20.3	77	74	75.5	3.38	6.0
7	-	34.3	22.2	77	74	75.5	2.10	5.0
8	-	35.2	26.2	91	81	86.0	3.24	6.0
9	-	34.3	26.1	90	82	86.0	5.79	4.0
10	-	33.5	26.7	90	82	86.0	6.45	6.0
11	-	33.9	25.6	87	81	84.5	4.63	4.0
12	-	34.0	26.0	83	89	86.0	4.33	3.8
13	3.7	36.4	24.8	87	82	84.5	4.18	2.7
14	31.2	34.8	24.0	100	88	94.0	4.85	3.2
15	0.2	32.9	23.8	100	84	92.0	2.88	6.2
16	60.2	32.8	23.0	91	77	84.0	3.97	1.2
17	-	32.7	24.4	87	81	84.0	1.53	3.6
18	-	33.8	20.7	86	70	78.0	2.34	4.0
19	-	33.3	20.0	74	64	69.0	2.03	5.0
20	-	34.2	20.3	91	64	82.5	2.90	7.0
21	-	34.1	21.0	78	77	77.5	3.61	7.0
22	-	31.8	21.2	76	86	81.0	0.99	7.0
23	-	32.7	23.4	91	77	84.0	2.42	6.0
24	-	32.9	22.0	91	81	86.0	5.25	5.0
25	-	30.1	18.8	86	77	81.5	4.15	3.4
26	-	30.0	17.7	54	63	58.5	1.91	3.0
27	-	31.3	20.0	75	69	72.0	3.70	3.2
28	-	31.0	14.7	75	66	70.5	2.48	2.8
29	-	30.9	15.2	66	54	60.0	2.85	2.0
30	-	31.8	14.0	70	62	66.0	2.50	1.8
31	-	30.9	12.8	79	65	72.0	2.25	1.9

TABLE A5: Table Showing Meterological Data for the Month of November 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
11	-	30.8	13.1	73	62	67.5	2.44	5.0
2	-	30.9	15.0	71.	59	65.0	2.63	4.0
3	-	31.2	14.3	94	62	79.0	2.80	4.0
4	-	30.0	14.1	74	58	68.0	3.42	4.0
5	-	30.1	13.4	78	65	71.5	4.69	5.0
6	-	30.2	12.4	78	61	69.5	3.41	4.0
7	-	28.8	13.3	73	55	64.0	3.87	4.0
8	-	30.1	12.0	73	55	64.0	3.90	4.0
9	-	30.0	12.8	73	68	70.5	2.57	4.0
10	-	30.1	12.7	73	72	72.5	1.73	3.0
11	-	30.3	12.8	64	65	64.5	0.68	4.0
12	-	30.0	12.9	73	62	67.5	2.07	3.0
13	-	30.8	12.7	94	76	85.0	3.03	3.0
14	-	30.9	13.5	94	75	84.5	2.35	3.0
15	-	28.7	11.1	72	71	71.5	1.95	4.0
16	-	28.1	10.0	66	71	68.5	2.11	3.0
17	-	28.0	11.3	72	83	77.5	2.30	3.0
18	-	27.8	11.4	62	74	68.0	1.90	3.0
19	-	26.7	10.5	44	78	61.0	1.75	3.0
20	-	27.3	13.3	83	78	80.5	2.15	4.0
21	-	26.1	15.0	94	86	90.0	1.56	2.0
22	-	23.1	10.0	81	59	70.0	1.24	2.0
23	-	25.7	10.3	81	70	75.5	1.58	4.0
24	-	25.0	7.8	73	73	73.0	0.91	3.0
25	-	25.1	8.4	76	76	76.0	1.08	3.0
26	-	26.0	7.9	86	77	81.5	0.44	2.0
27	-	25.2	8.0	67	70	68.5	1.24	2.0
28	-	25.7	10.7	76	57	66.5	1.70	2.0
29	-	25.2	12.2	70	58	64.0	4.56	2.0
30	-	25.0	10.3	75	51	63.0	4.79	3.0

TABLE A6: Table Showing Meterological Data for the Month of December 1974

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evapora-tion (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	25.8	9.0	64	60	62.0	5.58	4.0
2	-	25.9	8.1	68	78	73.0	2.78	4.0
3	-	24.7	14.2	82	78	80.0	3.89	2.0
4	-	24.5	11.7	58	77	67.5	3.75	2.0
5	-	23.1	10.0	81	76	78.5	3.52	4.0
6	-	23.2	7.2	67	80	73.5	2.72	3.0
7	-	21.0	6.8	66	70	68.5	3.86	2.0
8	-	21.2	7.1	79	76	77.5	2.57	3.0
9	-	21.6	9.2	74	77	75.5	1.40	2.0
10	-	23.6	8.2	73	71	72.0	1.95	1.0
11	-	20.9	7.5	86	66	76.0	3.38	3.0
12	-	21.2	6.4	85	67	76.0	5.80	3.0
13	-	22.3	9.1	86	59	72.5	4.68	3.0
14	-	23.1	8.2	68	59	63.5	3.92	3.0
15	-	22.7	11.7	82	73	77.5	5.72	3.0
16	4.8	24.3	13.8	94	76	85.0	10.40	1.0
17	4.0	21.8	14.5	100	100	100.0	8.68	2.0
18	3.0	16.9	12.0	100	89	94.5	5.50	1.0
19	-	18.3	10.6	100	88	94.0	4.15	1.0
20	-	16.4	7.3	85	78	81.5	3.18	1.0
21	-	17.1	6.0	85	78	81.5	2.58	2.0
22	-	17.2	6.1	79	84	81.5	2.20	2.0
23	-	18.3	6.0	85	74	79.5	2.63	2.0
24	-	20.6	4.5	85	80	82.5	2.16	2.0
25	-	19.7	6.2	73	79	76.0	2.32	2.0
26	-	18.7	6.1	65	61	63.0	2.78	2.0
27	-	19.5	6.8	79	54	66.5	1.49	3.0
28	-	21.5	7.0	69	58	63.5	3.18	2.0
29	-	22.0	6.9	69	71	70.0	3.73	2.0
30	-	18.7	9.0	80	62	71.0	2.90	3.0
31	-	18.3	7.9	85	64	74.5	3.58	2.0

TABLE A7: Table Showing Meterological Data for the Month of January 1975

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	16.9	10.0	71	85	78.0	6.35	2.0
2	-	20.1	9.1	93	82	87.5	7.52	3.0
3	-	14.6	6.4	100	83	91.5	2.92	1.0
4	-	17.3	6.8	92	89	90.5	2.58	1.0
5	-	19.2	6.7	78	85	81.5	3.38	2.0
6	-	19.9	6.0	71	80	75.5	2.65	1.0
7	-	20.1	5.8	77	71	74.0	2.45	2.0
8	-	20.8	6.1	85	85	85.0	1.64	2.0
9	-	21.0	8.2	93	90	91.5	5.18	2.0
10	-	22.1	9.3	86	80	83.0	5.17	2.0
11	-	20.8	9.4	93	80	86.5	4.72	2.0
12	-	20.3	9.5	86	75	80.5	4.42	3.0
13	-	19.2	7.5	85	70	77.5	5.64	3.0
14	-	19.4	5.5	85	79	82.0	5.98	4.0
15	-	19.0	6.8	78	75	76.5	3.68	3.0
16	-	21.3	8.9	80	81	80.5	2.36	3.0
17	-	22.8	10.0	86	75	80.5	1.53	3.0
18	-	20.7	5.6	77	74	75.5	5.24	3.0
19	-	19.1	4.5	69	74	71.5	4.18	2.0
20	-	20.4	3.8	83	74	78.5	2.12	3.0
21	-	22.5	6.0	87	94	90.5	3.02	2.0
22	3.0	17.6	12.2	93	89	91.0	12.45	1.0
23	-	18.3	11.4	100	89	94.5	10.56	2.0
24	-	16.6	10.3	100	84	92.0	4.40	1.0
25	-	20.4	5.7	84	79	81.5	2.67	2.0
26	-	17.8	6.0	85	74	79.5	3.34	3.0
27	-	18.5	5.8	86	73	79.5	3.45	3.0
28	-	20.3	5.9	77	80	78.5	4.53	3.0
29	-	21.7	7.9	86	74	80.0	5.75	3.0
30	-	20.2	6.8	85	75	80.0	2.65	2.0
31	-	20.5	9.0	93	81	87.0	4.39	2.0

TABLE A8: Table Showing Meterological Data for the Month of February 1975

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	24.1	10.1	93	72	82.5	4.22	2.4
2	-	22.3	6.0	71	75	73.0	6.20	4.0
3	-	20.2	5.0	70	39	54.5	5.36	3.8
4	-	21.5	4.1	77	47	62.0	5.20	3.5
5	-	22.7	8.0	82	81	81.5	2.25	3.4
6	-	22.4	10.8	81	90	85.5	5.95	4.1
7	-	22.9	10.3	86	69	77.5	2.97	3.2
8	-	23.6	10.0	80	65	72.5	4.45	3.3
9	-	24.7	11.5	76	53	64.5	5.93	3.5
10	-	23.8	11.0	81	68	74.5	7.45	4.0
11	1.2	22.9	11.3	93	76	84.5	5.68	3.0
12	-	22.8	9.3	86	53	69.5	4.35	3.8
13	-	24.1	11.8	69	63	66.0	5.51	3.5
14	4.7	29.3	14.9	94	85	89.5	8.56	5.6
15	-	23.4	12.0	88	77	82.5	4.77	3.0
16	-	23.2	10.9	80	70	75.0	5.67	3.5
17	-	20.7	6.2	71	65	68.0	6.32	4.0
18	-	20.1	4.1	70	70	70.0	6.95	4.0
19	-	20.8	6.1	78	79	78.5	4.16	3.0
20	-	18.8	9.3	78	85	81.5	3.94	1.0
21	-	22.7	10.1	93	69	81.0	3.68	2.0
22	-	24.1	11.6	93	56	74.5	4.65	3.0
23	-	24.2	8.0	74	73	73.5	5.16	3.0
24	-	24.4	9.2	74	53	63.5	3.70	3.1
25	-	25.3	10.2	71	62	66.5	3.71	4.0
26	-	26.2	11.6	77	58	67.5	2.90	4.0
27	-	26.0	10.7	71	56	63.5	1.83	3.0
28	-	28.4	10.5	75	58	66.5	2.10	4.0

TABLE A9: Table Showing Meterological Data for the Month of March 1975

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	32.1	13.2	73	46	59.5	2.86	5.0
2	-	31.4	14.1	73	41	57.0	5.47	5.0
3	-	29.3	13.8	43	41	42.0	8.50	7.0
4	-	33.0	14.3	53	49	51.0	5.87	6.0
5	-	35.4	20.2	64	64	64.0	5.20	6.0
6	-	30.3	20.1	85	78	81.5	7.55	6.0
7	-	29.9	14.0	89	75	82.0	9.78	4.0
8	-	30.7	15.5	89	58	73.5	4.38	5.0
9	-	32.8	16.0	75	61	68.0	3.60	7.0
10	-	29.5	15.8	84	56	69.0	3.50	5.0
11	-	31.4	14.5	64	39	51.5	6.63	6.0
12	-	30.3	16.3	62	45	53.5	5.49	6.0
13	-	33.2	10.1	55	30	42.5	7.41	6.0
14	-	29.5	10.9	55	32	43.5	9.15	6.0
15	-	29.6	11.4	53	36	44.5	7.28	6.0
16	-	30.1	10.8	58	32	45.0	6.71	6.0
17	-	30.7	10.3	55	30	42.5	5.75	6.0
18	-	32.8	13.4	54	32	43.0	6.79	7.0
19	-	30.5	13.2	51	29	40.0	6.57	8.0
20	-	34.7	15.5	57	31	44.0	6.13	7.0
21	-	33.2	15.6	63	42	52.5	3.50	6.0
22	-	31.6	14.7	76	49	62.5	2.01	6.0
23	-	34.5	21.4	60	49	54.5	3.93	7.0
24	-	36.2	19.7	60	67	63.5	5.88	6.0
25	1.2	33.2	16.5	84	70	77.0	6.92	5.2
26	6.2	29.8	12.5	77	48	62.5	5.55	4.2
27	-	30.1	12.3	72	47	59.5	4.18	5.0
28	-	34.8	15.0	61	38	49.5	6.20	7.0
29	-	31.7	15.1	57	37	47.0	7.07	8.0
30	-	33.8	16.5	55	35	45.0	4.28	7.0
31	-	33.6	17.1	53	37	45.0	7.67	8.0

TABLE A10: Table Showing Meterological Data for the Month of April 1975

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	36.0	15.9	55	39	47.0	7.84	8.5
2	-	37.7	16.1	61	42	51.5	8.44	10.6
3	-	38.8	16.7	63	46	54.5	7.92	10.5
4	-	41.2	19.5	65	48	56.5	8.60	10.0
5	-	40.6	18.7	67	44	55.5	7.80	10.0
6	-	41.5	19.6	72	48	60.0	9.10	11.0
7	-	42.7	20.5	70	49	59.5	8.23	10.5
8	-	40.5	20.0	68	40	54.0	5.45	9.5
9	-	41.2	20.3	72	38	55.0	6.40	9.5
10	-	42.8	21.4	70	39	54.5	10.80	10.0
11	-	40.8	20.6	71	43	57.0	11.45	9.0
12	-	39.7	19.8	75	45	60.0	10.90	8.0
13	-	39.8	18.5	76	44	60.0	11.20	8.0
14	-	40.7	20.1	69	39	54.0	9.34	9.0
15	-	41.5	20.5	70	40	55.0	10.25	10.0
16	-	41.6	20.7	71	38	54.5	8.40	9.5
17	-	39.5	19.7	75	40	57.5	5.14	8.5
18	-	40.8	20.1	78	37	57.5	6.08	9.0
19	-	38.5	19.0	79	38	58.5	5.93	9.0
20	-	39.6	20.0	76	43	59.5	10.70	8.8
21	-	37.5	18.8	78	45	61.5	9.89	8.7
22	-	40.2	20.1	68	39	53.5	12.34	9.0
23	-	41.3	22.0	70	41	55.5	10.45	9.8
24	-	41.4	23.0	70	40	55.0	8.56	9.6
25	-	42.0	24.5	69	38	53.5	6.39	10.0
26	-	41.8	23.8	71	39	55.0	8.94	11.5
27	-	42.1	25.1	70	38	54.0	10.64	10.0
28	-	41.4	25.0	69	39	54.0	11.50	10.5
29	-	41.0	25.0	70	38	54.0	9.72	11.0
30	-	40.0	24.8	68	39	53.5	9.81	11.0

TABLE A11: Table Showing Meterological Data for the Month of May 1975

Date	Rain-fall (mm)	Temperature °C		Relative Humidity (%)			Wind-speed Km/hr (at 4')	Class-A Pan Evaporation (mm/day)
		Max.	Min.	8 A.M.	2 P.M.	Average		
1	-	41.10	26.0	55	57	56.0	9.49	15.0
2	-	42.2	27.0	40	60	50.0	10.62	10.0
3	-	42.3	26.8	38	58	48.0	8.53	11.0
4	-	43.4	25.5	39	19	29.0	8.90	12.0
5	-	42.7	23.2	92	29	60.5	8.88	14.0
6	-	41.5	23.4	88	25	56.5	5.35	10.0
7	-	42.9	26.2	38	32	35.0	6.51	12.0
8	-	43.8	27.4	36	28	32.0	9.85	15.0
9	-	42.9	26.6	34	33	33.5	7.26	8.0
10	-	43.5	27.8	68	50	59.0	10.90	7.0
11	-	38.6	25.9	64	55	59.5	13.44	6.0
12	-	38.1	25.8	96	53	74.5	5.94	14.0
13	-	42.4	27.7	92	59	75.5	7.86	13.0
14	-	39.3	29.0	56	37	46.5	2.86	12.0
15	-	38.9	27.2	58	43	50.5	10.62	11.0
16	-	40.8	22.3	66	62	64.0	13.44	5.0
17	-	35.7	24.1	65	47	56.0	5.59	11.0
18	-	37.3	24.8	65	46	55.5	6.29	11.0
19	-	40.8	25.5	64	71	67.5	3.96	12.0
20	-	41.2	23.1	58	36	47.0	5.43	9.0
21	-	40.2	26.0	54	33	43.5	4.65	9.0
22	-	41.3	26.3	56	38	47.0	4.82	11.0
23	-	41.1	27.3	50	53	51.5	6.48	11.0
24	-	40.2	25.4	53	34	43.5	3.25	8.0
25	-	41.1	28.6	47	41	44.0	5.03	11.0
26	-	36.7	24.9	49	38	43.5	5.57	6.0
27	-	37.5	26.8	57	46	51.5	4.39	8.0
28	-	41.0	28.7	54	38	46.0	7.01	11.0
29	-	40.2	28.0	60	40	50.0	6.18	8.0
30	-	41.8	28.1	53	37	45.0	6.67	11.0
31	-	42.3	26.9	50	35	42.5	8.45	13.0

TABLE A12: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of August 1974

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft.
1	5.8	7.0	7.9	9.1	9.8	81	-	-
2	5.2	5.8	6.5	7.4	8.5	78	-	-
3	4.0	4.6	5.5	6.2	7.4	91	90	93
4	4.0	5.0	5.8	6.7	7.8	93	91	93
5	3.9	5.0	6.0	6.8	8.0	93	93	93
6	2.5	3.0	3.7	4.5	5.6	93	93	93
7	2.8	3.6	4.2	5.0	6.1	93	93	93
8	2.4	3.0	4.0	4.8	5.9	94	93	93
9	3.6	4.6	5.8	6.7	7.3	93	93	93
10	3.7	4.6	5.7	6.5	7.2	93	93	93
11	3.3	4.3	5.3	6.4	7.5	92	93	93
12	4.6	5.5	6.4	7.3	8.0	93	93	93
13	3.8	4.7	5.5	6.4	7.5	91	93	93
14	4.3	5.4	6.2	7.0	8.0	90	93	93
15	4.1	5.0	6.0	7.2	8.1	91	93	93
16	4.5	5.4	6.5	7.4	8.5	93	93	93
17	4.8	5.8	7.0	7.8	8.7	92	93	93
18	4.5	5.6	6.8	7.9	8.6	93	93	93
19	4.9	5.8	6.7	7.7	8.8	93	93	93
20	3.0	4.0	5.0	6.4	7.2	93	93	93
21	6.5	7.5	8.4	8.8	9.6	93	93	93
22	4.1	5.0	6.0	6.8	7.6	93	93	93
23	4.3	5.2	6.1	7.0	8.0	93	93	93
24	3.8	4.7	5.6	6.7	7.8	93	93	93
25	2.5	3.0	3.5	4.4	5.4	93	93	93
26	4.0	5.0	5.7	6.5	7.5	92	93	93
27	6.0	7.0	8.2	9.0	10.3	90	93	93
28	3.6	4.5	5.4	6.2	7.0	93	93	93
29	6.0	7.0	8.0	8.6	9.8	91	93	93
30	4.0	5.0	6.0	6.7	7.8	89	92	93
31	8.0	9.0	9.8	10.7	11.2	86	91	93

TABLE A13: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of September 1974

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	7.0	8.0	9.0	9.9	10.8	82	88	89
2	6.8	7.8	8.5	9.6	10.5	79	85	88
3	7.0	8.0	8.8	9.8	10.7	73	82	87
4	7.0	7.9	8.8	10.0	10.7	67	80	87
5	6.0	6.5	7.4	8.3	8.9	62	76	85
6	6.1	6.8	7.7	8.6	9.5	56	71	81
7	9.0	10.0	11.0	11.8	12.9	92	71	81
8	8.0	9.0	9.7	10.5	11.5	90	93	83
9	6.0	7.0	7.7	8.7	9.6	87	93	92
10	2.0	2.5	3.2	4.1	4.8	93	93	93
11	7.0	8.0	8.8	9.6	10.5	93	93	93
12	5.0	5.8	6.5	7.4	8.5	91	93	93
13	6.0	7.0	8.0	8.8	9.6	88	90	91
14	6.0	7.0	8.0	9.0	10.0	84	88	89
15	4.1	5.0	6.8	6.7	7.8	80	87	88
16	4.8	5.9	7.0	7.7	8.5	75	84	86
17	4.0	5.0	6.0	6.8	7.9	71	80	85
18	6.0	7.0	8.0	8.8	9.8	65	77	81
19	4.0	5.0	5.8	6.7	7.8	59	72	79
20	4.0	5.0	5.7	6.7	7.7	53	66	77
21	4.0	5.1	6.0	7.0	8.0	46	60	74
22	3.9	5.0	5.7	6.6	7.5	92	62	74
23	2.0	3.0	3.7	4.8	5.7	91	91	84
24	1.8	2.8	3.5	4.5	5.6	93	93	93
25	1.2	2.0	3.0	3.8	4.6	92	93	93
26	3.0	4.0	5.0	5.9	6.9	91	93	93
27	3.2	4.0	5.1	5.9	6.8	88	90	91
28	3.4	4.3	5.3	6.1	7.0	84	88	89
29	2.0	3.0	4.0	5.0	5.9	91	88	88
30	1.8	2.9	4.0	5.0	5.8	93	92	91

TABLE A14: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of October - 1974

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	5.0	6.0	7.0	8.0	8.8	91	92	93
2	6.0	7.0	7.8	8.7	9.6	88	90	93
3	6.0	6.8	7.7	8.7	9.8	85	90	91
4	5.8	6.9	7.8	8.8	9.7	81	87	89
5	6.0	7.0	8.0	8.8	9.8	76	85	88
6	6.1	7.0	8.1	8.9	9.9	70	82	87
7	4.8	6.0	6.8	7.8	8.9	65	78	87
8	6.0	7.0	7.9	8.8	9.8	59	75	85
9	3.8	4.9	6.0	7.0	8.0	55	71	83
10	6.0	7.0	7.7	8.8	9.9	50	68	81
11	4.0	5.0	6.0	6.8	8.0	44	64	78
12	3.8	4.5	5.5	6.6	8.1	37	60	75
13	2.5	3.2	4.0	5.0	6.2	91	60	75
14	3.4	4.5	5.6	6.4	7.5	89	91	79
15	6.0	7.0	8.0	8.8	9.8	93	93	92
16	1.4	2.5	3.5	4.6	5.5	93	93	93
17	3.5	4.5	5.6	6.5	7.4	92	93	93
18	4.0	5.0	6.0	7.0	8.2	90	92	93
19	4.8	5.8	6.8	8.0	8.8	88	90	91
20	7.0	7.0	9.0	9.8	10.9	85	88	89
21	7.0	8.1	9.2	10.2	11.2	81	88	89
22	6.8	7.5	8.6	9.7	10.8	78	86	88
23	6.0	7.0	7.8	8.7	9.6	73	85	88
24	5.5	6.4	7.5	8.4	9.2	69	81	87
25	3.5	4.5	5.4	6.5	7.7	65	78	85
26	3.0	4.0	5.0	5.8	6.9	61	76	85
27	3.2	4.3	5.0	5.7	6.8	58	76	84
28	2.8	3.8	4.7	5.5	6.6	56	75	83
29	2.0	3.0	4.0	5.1	6.1	53	73	83
30	2.0	3.0	4.2	5.2	6.3	50	71	82

TABLE A15: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of November 1974

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	5.0	6.0	6.9	7.8	8.6	46	68	81
2	4.1	5.0	6.2	7.3	8.2	41	66	81
3	4.0	5.1	6.0	7.0	8.4	37	63	80
4	4.2	5.0	6.1	7.0	8.5	31	60	78
5	5.0	5.8	6.5	7.4	8.8	25	56	76
6	3.8	4.5	5.6	6.4	8.0	20	52	74
7	4.0	4.8	5.7	6.5	8.0	16	46	71
8	3.9	4.9	5.8	6.7	8.0	11	40	67
9	4.0	5.0	6.0	6.8	8.1	6	33	64
10	3.2	4.0	5.0	6.2	7.1	0	28	60
11	3.8	4.9	6.0	6.9	7.8	0	22	55
12	3.1	4.0	5.0	6.0	7.2	0	15	49
13	3.0	4.0	5.1	6.0	7.1	90	15	49
14	3.3	4.4	5.5	6.4	7.5	91	88	50
15	4.5	5.5	6.4	7.2	8.4	90	92	90
16	3.0	4.0	5.0	5.8	7.0	88	91	93
17	3.0	4.0	5.1	5.9	7.1	86	90	91
18	3.0	4.1	5.1	6.0	7.2	83	88	89
19	2.8	3.8	4.7	5.6	6.8	81	86	89
20	4.0	5.0	6.0	7.0	8.1	78	85	88
21	2.0	3.0	3.8	4.9	6.0	76	83	87
22	2.0	3.1	4.0	5.0	6.0	73	81	87
23	3.8	4.7	5.6	6.5	7.6	70	80	86
24	3.0	4.0	5.1	6.0	7.2	66	78	86
25	3.0	4.0	5.0	6.1	7.2	62	76	84
26	2.0	3.0	4.0	4.8	5.9	57	71	80
27	2.2	3.0	4.1	5.2	6.3	53	65	78
28	2.0	3.0	4.0	5.0	6.2	50	61	75
29	2.0	3.1	4.0	5.0	6.1	46	57	71
30	3.0	4.0	4.8	5.7	6.8	41	52	65

TABLE A16: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of December 1974

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	4.0	4.8	5.7	6.5	7.6	36	50	61
2	3.8	4.5	5.6	6.5	7.5	30	44	56
3	2.0	3.0	4.0	5.1	6.2	24	39	51
4	2.0	3.0	3.8	4.9	6.1			
5	3.8	4.7	5.8	6.6	7.8			
6	3.2	4.0	5.1	6.5	8.0			
7	2.0	3.0	4.0	5.2	6.5			
8	3.0	4.0	5.0	6.0	7.5			
9	2.0	3.0	4.0	5.0	6.5			
10	1.0	2.1	3.2	4.0	5.5			
11	2.5	3.5	4.3	5.2	6.2			
12	3.0	4.0	4.6	5.5	6.8			
13	3.0	4.1	5.2	6.0	7.3			
14	3.0	4.0	5.1	6.0	7.2			
15	2.8	3.8	5.0	5.8	6.9			
16	1.8	3.0	4.1	5.0	6.2			
17	2.0	3.0	4.0	5.0	6.3			
18	1.5	2.6	3.8	5.0	6.0			
19	1.0	2.0	3.0	4.1	5.2			
20	0.7	2.0	3.1	4.2	5.0			
21	2.0	3.0	4.0	5.1	6.2			
22	2.0	3.0	4.0	5.0	6.2			
23	2.0	3.1	4.1	5.2	6.3			
24	1.8	3.0	4.0	5.0	6.1			
25	1.7	2.8	3.9	5.1	6.0			
26	2.0	3.0	4.1	5.2	6.2			
27	3.0	4.0	5.0	6.1	7.2			
28	2.0	3.0	4.0	4.8	5.6			
29	1.8	2.8	3.9	5.0	6.1			
30	3.1	4.2	5.3	6.4	7.5			
31	2.0	3.0	4.0	5.1	6.2			

TABLE A17: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of February 1975

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in. Tensi-meter	1.5 ft	2 ft
13	4.0	4.8	5.6	6.8	8.0	0	-	-
14	5.5	6.4	7.5	8.4	9.4	6	-	-
15	3.2	4.0	5.1	6.0	7.2	30	-	-
16	3.8	4.6	5.7	6.5	7.5	55	-	-
17	4.5	5.0	6.0	7.1	8.2	82	-	-
18	3.8	4.5	5.7	6.8	7.5	94	92	93
19	3.0	4.0	5.0	6.0	7.5	90	90	91
20	1.5	2.0	2.8	3.9	5.0	87	88	89
21	1.5	2.4	3.2	4.4	5.5	86	88	89
22	3.6	4.0	4.7	5.6	6.8	84	87	89
23	3.0	4.0	4.8	5.5	6.6	83	86	88
24	3.4	4.1	4.9	5.6	6.8	80	86	87
25	3.8	4.5	5.2	6.4	7.5	76	85	87
26	4.0	5.0	5.8	6.7	7.8	71	84	87
27	3.2	4.2	5.1	6.5	7.5	67	84	86
28	4.3	5.0	6.0	6.8	7.9	61	83	85

TABLE A18: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of March 1975

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	5.0	6.0	6.7	7.8	9.0	55	82	85
2	4.0	5.2	6.3	7.5	8.6	49	80	84
3	6.0	7.0	8.0	9.1	10.5	92	80	84
4	7.0	8.1	9.0	10.2	11.4	90	93	90
5	6.0	7.0	8.0	9.0	10.4	85	93	94
6	6.0	7.1	7.9	8.8	10.2	81	91	94
7	4.8	6.0	7.1	8.2	9.5	79	90	93
8	5.2	6.2	7.0	8.1	9.4	74	89	90
9	7.0	8.0	9.1	10.2	11.3	68	86	83
10	5.4	6.3	7.5	8.5	9.8	61	85	88
11	6.2	7.0	8.1	9.0	10.4	53	83	87
12	6.0	6.8	8.0	8.9	10.1	90	81	85
13	6.1	7.0	8.0	9.1	10.3	91	92	90
14	6.0	7.2	8.3	9.5	10.8	88	91	93
15	6.2	7.0	7.8	9.0	10.5	85	90	93
16	6.0	7.0	7.9	9.2	10.5	81	88	91
17	6.0	7.1	8.2	9.3	10.6	76	85	88
18	7.0	8.0	9.1	10.2	11.5	72	84	87
19	7.8	8.9	10.0	11.2	12.5	67	84	87
20	7.5	8.4	9.5	10.6	11.8	61	83	86
21	6.0	7.2	8.0	9.1	10.6	56	82	85
22	6.2	7.4	8.5	9.5	10.8	49	80	84
23	7.4	8.5	9.6	10.8	12.0	91	80	84
24	6.0	7.2	8.5	9.8	10.8	89	92	91
25	5.7	6.5	6.6	7.8	8.9	86	92	93
26	4.5	5.6	6.7	8.0	9.5	88	93	92
27	5.5	6.7	7.5	8.6	10.0	84	89	92
28	7.4	8.5	9.5	10.7	11.8	79	87	91
29	8.2	9.5	10.6	11.8	13.0	74	85	91
30	7.2	8.3	9.5	10.7	11.8	70	83	90
31	8.4	9.5	10.5	11.6	13.0	65	80	89

TABLE A19: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of April 1975

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	10.7	12.0	12.8	13.5	15.0	59	77	88
2	10.5	11.0	13.0	14.4	15.0	52	73	87
3	11.0	12.0	14.0	14.8	16.2	90	73	87
4	11.0	12.0	13.5	14.6	16.0	88	91	88
5	10.8	11.6	13.0	14.2	15.8	84	89	92
6	11.4	12.5	13.8	14.9	16.4	80	87	92
7	10.9	12.0	13.0	14.4	15.6	75	84	90
8	9.5	10.8	12.0	13.0	15.0	69	80	89
9	9.6	10.8	12.0	13.0	15.2	62	75	87
10	10.4	11.5	12.6	13.5	14.8	53	69	86
11	9.8	10.8	12.0	13.4	14.9	90	69	86
12	8.8	10.0	11.0	12.0	14.0	87	92	88
13	8.5	10.0	10.8	12.2	14.0	83	90	93
14	9.4	10.5	11.5	12.8	14.5	78	87	93
15	10.5	11.5	12.5	13.8	14.6	72	83	91
16	10.0	12.0	12.0	13.5	15.0	65	79	89
17	9.0	10.0	11.4	12.8	14.0	58	74	87
18	9.3	10.0	11.5	12.5	14.0	50	68	86
19	9.4	10.2	11.6	12.8	14.2	41	63	84
20	9.0	10.0	11.4	12.5	13.8	31	57	81
21	9.3	10.5	11.6	12.8	14.4	92	57	81
22	9.2	10.0	11.0	12.5	14.0	89	91	87
23	10.0	11.0	12.5	13.6	14.8	86	89	93
24	10.0	11.2	12.5	13.5	15.0	82	89	91
25	10.5	12.0	13.0	14.5	16.0	75	86	89
26	12.0	12.3	13.8	14.8	16.0	59	82	88
27	11.0	12.5	13.6	14.5	15.8	62	78	88
28	11.5	12.4	13.8	14.6	15.9	56	73	87
29	11.6	12.2	13.5	14.4	15.7	48	68	86
30	11.7	13.0	14.0	14.8	16.0	39	62	84

TABLE A20: Table Showing the Evaporation from Ordinary Can and Soil Moisturemeter Readings for the Month of May 1975

Date	Evaporation from Ordinary Cans (mm)					Moisturemeter Reading		
	Burial Percentage					Depth of Moisture Block		
	100	75	50	25	0	6 in.	1.5 ft	2 ft
1	15.4	15.8	16.7	17.5	18.8	28	54	80
2	10.8	12.0	13.5	14.6	16.0	92	54	80
3	12.0	12.8	14.0	15.2	16.3	88	90	86
4	12.8	14.0	14.0	15.4	16.5	84	87	92
5	13.5	14.5	15.5	17.0	18.0	78	85	90
6	10.7	11.5	12.6	13.5	15.0	71	81	88
7	12.6	13.5	14.0	15.5	16.8	63	76	87
8	15.5	16.5	17.0	18.0	19.6	54	70	85
9	9.0	10.0	11.4	12.5	13.6	46	65	83
10	7.8	8.9	10.2	11.4	13.0	39	59	81
11	6.5	7.6	8.5	9.4	10.5	30	51	78
12	14.2	15.6	15.8	17.0	18.2	91	51	78
13	13.5	14.2	15.4	16.4	17.5	87	92	84
14	12.0	13.0	13.8	14.6	16.0	82	91	93
15	11.5	12.5	14.0	15.0	16.0	76	89	90
16	6.0	6.9	7.8	8.8	10.0	70	86	88
17	10.8	11.7	12.5	13.5	15.0	62	82	86
18	11.3	12.3	13.5	14.5	15.6	53	76	83
19	12.0	13.0	13.7	14.8	16.0	43	71	80
20	9.2	10.3	11.3	12.5	13.8	34	65	76
21	9.5	10.5	11.5	12.4	14.0	23	57	70